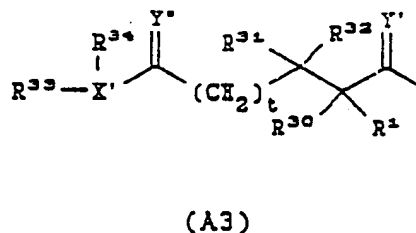
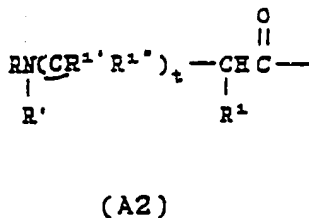
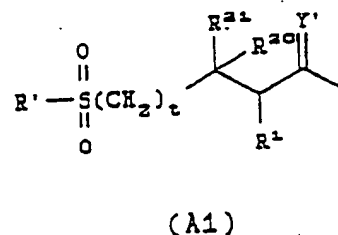
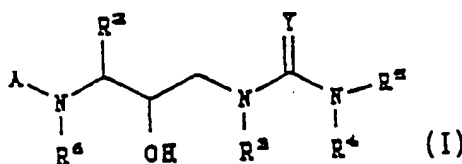




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<p>(21) International Application Number: PCT/US91/08613 (22) International Filing Date: 18 November 1991 (18.11.91) (30) Priority data: 615,210 19 November 1990 (19.11.90) US (60) Parent Application or Grant (63) Related by Continuation US 615,210 (CIP) Filed on 19 November 1990 (19.11.90) (71) Applicants (for all designated States except US): MONSANTO COMPANY [US/US]; 800 North Lindbergh Boulevard, St. Louis, MO 63167 (US). G.D. SEARLE &amp; COMPANY [US/US]; 5200 Old Orchard Road, Skokie, IL 60077 (US). (72) Inventors; and (75) Inventors/Applicants (for US only): CLARE, Michael [GB/US]; 5154 West Brown Street, Skokie, IL 60077 (US). DECRESCENZO, Gary, Anthony [US/US]; 536 Schrader Farm Drive, St. Peters, MO 63376 (US). FRESKOS, John, Nicholas [US/US]; 7572 York, Clayton, MO 63105 (US). GETMAN, Daniel, Paul [US/US]; 12944 Summit Ridge Drive, St. Louis, MO 63146 (US). HEINTZ, Robert, Martin [US/US]; 603 Nancy Place, Ballwin, MO 63021 (US). LIN, Ko-Chung [CN/US]; 12790 Polo Parc Drive, St. Louis, MO 63146 (US). MUELLER, Richard, August [US/US]; 562 Stonegate Terrace, Glencoe, IL 60022 (US). REED, Kathryn, Lea [US/</p>		<p>(43) International Publication Date: 29 May 1992 (29.05.92)</p> <p>US); 1103 Claytonia Terrace, Richmond Heights, MO 63117 (US). TALLEY, John, Jeffrey [US/US]; 1510 Amisk Court, Chesterfield, MO 63017 (US). VAZQUEZ, Michael, Lawrence [US/US]; 233 Saratoga Court, Gurnee, IL 60031 (US). SUN, Eric, Tak, On [US/US]; 1647 Johnson Drive, Apartment 433, Buffalo Grove, IL 60039 (US).</p> <p>(74) Agent: BOLDING, James, Clifton; Monsanto Company, 800 North Lindbergh Boulevard, St. Louis, MO 63167 (US).</p> <p>(81) Designated States: AT (European patent), AU, BE (European patent), BF (OAPI patent), BJ (OAPI patent), CA, CF (OAPI patent), CG (OAPI patent), CH (European patent), CI (OAPI patent), CM (OAPI patent), CS, DE (European patent), DK (European patent), ES (European patent), FI, FR (European patent), GA (OAPI patent), GB (European patent), GN (OAPI patent), GR (European patent), HU, IT (European patent), JP, KR, LU (European patent), ML (OAPI patent), MR (OAPI patent), NL (European patent), NO, PL, SE (European patent), SN (OAPI patent), SU*, TD (OAPI patent), TG (OAPI patent), US.</p> <p><b>Published</b> With international search report. Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.</p>

(54) Title: RETROVIRAL PROTEASE INHIBITORS



## (57) Abstract

Compounds represented by formula (I) wherein A represents radicals represented by formulae (A1, A2, A3) (values for the variables given herein), are effective as retroviral protease inhibitors, and in particular as inhibitors of HIV protease.

# + DESIGNATIONS OF "SU"

Any designation of "SU" has effect in the Russian Federation. It is not yet known whether any such designation has effect in other States of the former Soviet Union.

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RETROVIRAL PROTEASE INHIBITORS

This application is a continuation-in-part of U. S. Patent Application Serial No. 07/615,210, filed November 19, 1990.

5                   BACKGROUND OF THE INVENTION1. Field of the Invention

The present invention relates to retroviral protease inhibitors and, more particularly, relates to novel compounds and a composition and method for  
10 inhibiting retroviral proteases. This invention, in particular, relates to urea-containing hydroxyethylamine protease inhibitor compounds, a composition and method for inhibiting retroviral proteases such as human immunodeficiency virus (HIV) protease and for treating a  
15 retroviral infection, e.g., an HIV infection. The subject invention also relates to processes for making such compounds as well as to intermediates useful in such processes.

2. Related Art

20                   During the replication cycle of retroviruses, gag and gag-pol gene products are translated as proteins. These proteins are subsequently processed by a virally encoded protease (or proteinase) to yield viral enzymes and structural proteins of the virus core.  
25 Most commonly, the gag precursor proteins are processed into the core proteins and the pol precursor proteins are processed into the viral enzymes, e.g., reverse transcriptase and retroviral protease. It has been shown that correct processing of the precursor proteins  
30 by the retroviral protease is necessary for assembly of infectious virions. For example, it has been shown that frameshift mutations in the protease region of the pol gene of HIV prevents processing of the gag precursor protein. It has also been shown through site-directed  
35 mutagenesis of an aspartic acid residue in the HIV protease that processing of the gag precursor protein is prevented. Thus, attempts have been made to inhibit

-2-

viral replication by inhibiting the action of retroviral proteases.

Retroviral protease inhibition typically involves a transition-state mimetic whereby the

5 retroviral protease is exposed to a mimetic compound which binds (typically in a reversible manner) to the enzyme in competition with the gag and gag-pol proteins to thereby inhibit replication of structural proteins and, more importantly, the retroviral protease itself.

10 In this manner, retroviral replication proteases can be effectively inhibited.

Several classes of mimetic compounds have been proposed, particularly for inhibition of proteases, such as for inhibition of HIV protease. Such mimetics

15 include hydroxyethylamine isosteres and reduced amide isosteres. See, for example, EP O 346 847; EP O 342,541; Roberts et al, "Rational Design of Peptide-Based Proteinase Inhibitors," Science, 248, 358 (1990); and Erickson et al, "Design Activity, and 2.8Å

20 Crystal Structure of a C<sub>2</sub> Symmetric Inhibitor Complexed to HIV-1 Protease," Science, 249, 527 (1990).

Several classes of mimetic compounds are known to be useful as inhibitors of the proteolytic enzyme renin. See, for example, U.S. No. 4,599,198; U.K.

25 2,184,730; G.B. 2,209,752; EP O 264 795; G.B. 2,200,115 and U.S. SIR H725. Of these, G.B. 2,200,115, GB 2,209,752, EP O 264,795, U.S. SIR H725 and U.S. 4,599,198 disclose urea-containing hydroxyethylamine renin inhibitors. However, it is known that, although

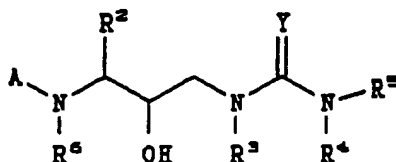
30 renin and HIV proteases are both classified as aspartyl proteases, compounds which are effective renin inhibitors generally cannot be predicted to be effective HIV protease inhibitors.

BRIEF DESCRIPTION OF THE INVENTION

Th present invention is directed to virus inhibiting compounds and compositions. More particularly, the present invention is directed to retroviral protease inhibiting compounds and compositions, to a method of inhibiting retroviral proteases, to processes for preparing the compounds and to intermediates useful in such processes. The subject compounds are characterized as urea-containing hydroxyethylamine inhibitor compounds.

DETAILED DESCRIPTION OF THE INVENTION

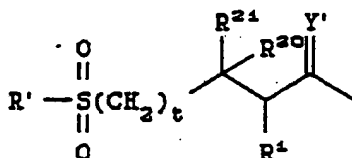
In accordance with the present invention, there is provided a retroviral protease inhibiting compound of the formula:



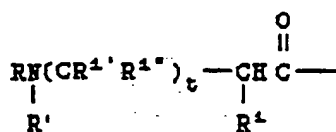
(Formula I)

or a pharmaceutically acceptable salt, prodrug or ester thereof wherein:

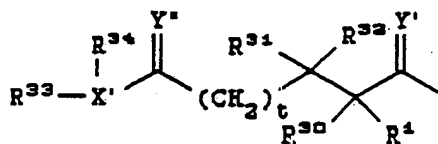
A represents radicals represented by the formulas:



(A1)



(A2)



(A3)

wherein

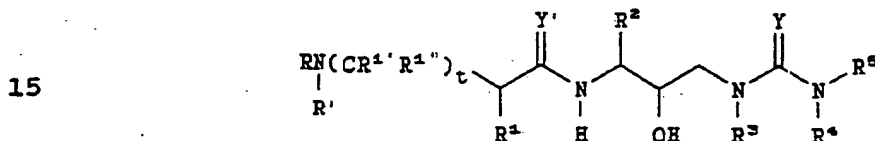
- R represents hydrogen, alkoxycarbonyl, aralkoxycarbonyl, alkylcarbonyl, cycloalkylcarbonyl, cycloalkylalkoxycarbonyl, cycloalkylalkanoyl, alkanoyl, aralkanoyl, aroyl, aryloxycarbonyl, aryloxyalkanoyl, heterocyclylcarbonyl, heterocyclyloxycarbonyl, heterocyclylalkanoyl, heterocyclylalkoxycarbonyl, heteroaralkoxycarbonyl, hetroaryloxycarbonyl, heteroaroyl, alkyl, aryl, aralkyl, aryloxyalkyl, heteroaryloxyalkyl, hydroxyalkyl, alkylaminocarbonyl, arylaminocarbonyl, aralkylaminoalkylcarbonyl, aminoalkanoyl, alkylaminoalkylcarbonyl, and mono- and disubstituted aminoalkanoyl radicals wherein the substituents are selected from alkyl, aryl, aralkyl, cycloalkyl, cycloalkylalkyl, heteroaryl, heteroaralkyl, heterocycloalkyl, heterocycloalkyalkyl radicals;

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- R' represents hydrogen and radicals as defined for R<sup>3</sup> or R and R' together with the nitrogen to which they are attached form a heterocycloalkyl or heteraryl radical;
- 5 t represents either 0 or 1;
- R<sup>1</sup> represents hydrogen, -CH<sub>2</sub>SO<sub>2</sub>NH<sub>2</sub>, CO<sub>2</sub>CH<sub>3</sub>, CONH<sub>2</sub>, alkyl, alkenyl, alkynyl and cycloalkyl radicals and amino acid side chains selected from asparagine, S-methyl cysteine and the corresponding sulfoxide and sulfone derivatives
- 10 thereof, glycine, leucine, isoleucine, allo-isoleucine, tert-leucine, phenylalanine, ornithine, alanine, histidine, norleucine, glutamine, valine, threonine, serine, aspartic acid, beta-cyano alanine, and allothreonine side chains;
- 15 R<sup>1'</sup> and R<sup>1''</sup> independently represent hydrogen and radicals as defined for R<sup>1</sup>;
- R<sup>2</sup> represents alkyl, aryl, cycloalkyl, cycloalkylalkyl and aralkyl radicals, which radicals are optionally substituted with a group selected
- 20 from -NO<sub>2</sub>, -OR<sup>9</sup>, -SR<sup>9</sup>, and halogen radicals, wherein R<sup>9</sup> represents hydrogen and alkyl radicals;
- R<sup>3</sup> represents alkyl, alkenyl, hydroxyalkyl, cycloalkyl, cycloalkylalkyl, heterocycloalkyl, heteroaryl, heterocycloalkylalkyl, aryl, aralkyl, and
- 25 heteroaralkyl radicals;
- X' represents O, C(R<sup>17</sup>) where R<sup>17</sup> represents hydrogen and alkyl radicals, and N;
- Y, Y', and Y'' independently represent O, S and NR<sup>15</sup> wherein R<sup>15</sup> represents hydrogen and radicals as defined
- 30 for R<sup>3</sup>;
- R<sup>4</sup> and R<sup>5</sup> independently represent hydrogen and radicals as defined by R<sup>3</sup>, or R<sup>4</sup> and R<sup>5</sup> together with the nitrogen atom to which they are bonded represent heterocycloalkyl and heteroaryl radicals;
- 35 R<sup>6</sup> represents hydrogen and radicals as defined for R<sup>3</sup>;
- R<sup>20</sup>, R<sup>21</sup>, R<sup>30</sup>, R<sup>31</sup> and R<sup>32</sup> represent radicals as defined for R<sup>1</sup>, or one of R<sup>1</sup> and R<sup>30</sup> together with one of R<sup>31</sup> and

$R^{32}$  and the carbon atoms to which they are attached form a cycloalkyl radical; and  
 $R^{33}$  and  $R^{34}$  independently represent hydrogen and radicals as defined for  $R^3$ , or  $R^{33}$  and  $R^{34}$  together with  $X'$   
 5 represent cycloalkyl, aryl, heterocyclyl and heteroaryl radicals, provided that when  $X'$  is O,  $R^{34}$  is absent.

A preferred class of retroviral inhibitor compounds of the present invention are those represented  
 10 by the formula:



20 (Formula II)  
 or a pharmaceutically acceptable salt, prodrug or ester thereof, preferably wherein the stereochemistry about the hydroxy group is designated as (R);  
 R represents hydrogen, alkoxycarbonyl, aralkoxycarbonyl,  
 25 alkylcarbonyl, cycloalkylcarbonyl, cycloalkylalkoxycarbonyl, cycloalkylalkanoyl, alkanoyl, aralkanoyl, aroyl, aryloxycarbonyl, aryloxyalkanoyl, heterocyclylcarbonyl, heterocyclylloxycarbonyl, heterocyclylalkanoyl,  
 30 heterocyclylalkoxycarbonyl, heteroaralkoxycarbonyl, hetroaryloxycarbonyl, heteroaroyl, alkyl, aryl, aralkyl, aryloxyalkyl, heteroaryloxyalkyl, hydroxyalkyl, alkylaminocarbonyl, arylaminocarbonyl, aralkylaminoalkylcarbonyl, aminoalkanoyl,  
 35 alkylaminoalkylcarbonyl, and mono- and disubstituted aminoalkanoyl radicals wherein the substituents are selected from alkyl, aryl, aralkyl, cycloalkyl, cycloalkylalkyl, heteroaryl, heteroaralkyl, heterocycloalkyl, heterocycloalkyl radicals;  
 40  $R'$  represents hydrogen and radicals as defined for  $R^3$  or R and  $R'$  together with the nitrogen to which they are



attach and represent heterocycloalkyl and heteroaryl radical;

- $R^1$  represents hydrogen,  $-\text{CH}_2\text{SO}_2\text{NH}_2$ ,  $\text{CO}_2\text{CH}_3$ ,  $\text{CONH}_2$ , alkyl and cycloalkyl radicals, and amino acid side chains selected from asparagine, S-methyl cysteine and the sulfoxide (SO) and sulfone ( $\text{SO}_2$ ) derivatives thereof, isoleucine, allo-isoleucine, alanine, leucine, tert-leucine, phenylalanine, ornithine, histidine, norleucine glutamine, threonine, glycine, allo-threonine, serine, aspartic acid, beta-cyano alanine and valine side chains;
- $R^{1'}$  and  $R^{1''}$  independently represent hydrogen and radicals as defined for  $R^1$ ;
- $R^2$  represents alkyl, aryl, cycloalkyl, cycloalkylalkyl, and aralkyl radicals, which radicals are optionally substituted with a group selected from alkyl radicals,  $\text{NO}_2$ ,  $\text{OR}^9$  and  $\text{SR}^9$  wherein  $R^9$  represents hydrogen and alkyl radicals, and halogen radicals;
- $R^3$  represents alkyl, cycloalkyl, cycloalkylalkyl, heterocycloalkyl, heterocycloalkylalkyl, aryl, heteroaryl, aralkyl and heteroaralkyl radicals; and  $R^4$  and  $R^5$  independently represent hydrogen and radicals as defined by  $R^3$ , or together with a nitrogen atom to which they are bonded represent heterocycloalkyl and heteroaryl radicals;

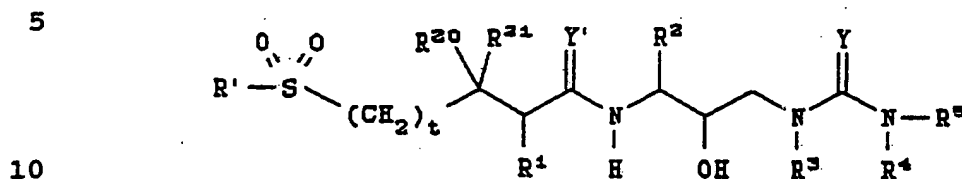
t represents 0 or 1;

Y and Y' independently represent O, S, and  $\text{NR}^{15}$  wherein  $R^{15}$  represents hydrogen and radicals as defined for  $R^3$ .

- 30 Preferably, Y and Y' represent O.

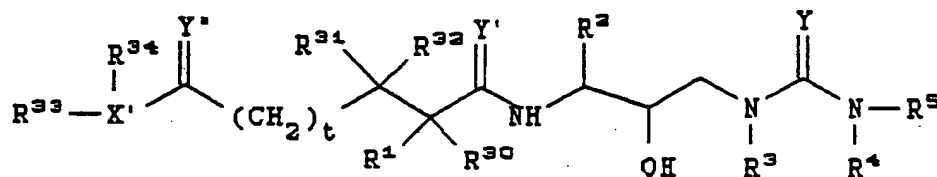
Preferably,  $R^3$  represents radicals as defined above which contain no  $\alpha$ -branching, e.g., as in an isopropyl radical or a t-butyl radical. The preferred radicals are those which contain a  $-\text{CH}_2-$  moiety between the nitrogen of the urea and the remaining portion of the radical. Such preferred groups include, but are not limited to, benzyl, isobutyl, n-butyl, isoamyl, cyclohexylmethyl and the like.

Another preferred class of compounds are those represented by the formula:



15 (Formula III)  
or a pharmaceutically acceptable salt, prodrug or ester thereof wherein t, Y, Y', R', R<sup>1</sup>, R<sup>2</sup>, R<sup>3</sup>, R<sup>4</sup>, R<sup>5</sup>, R<sup>20</sup> and R<sup>21</sup> are as defined above.

20 Yet another preferred class of compounds are those represented by the formula:



25 (Formula IV)  
or a pharmaceutically acceptable salt, prodrug or ester thereof, preferably wherein the stereochemistry about the hydroxy group is designated as R, wherein t, X', Y, Y', Y'', R<sup>1</sup>, R<sup>2</sup>, R<sup>3</sup>, R<sup>4</sup>, R<sup>5</sup>, R<sup>30</sup>, R<sup>31</sup>, R<sup>32</sup>, R<sup>33</sup> and R<sup>34</sup> are as defined above.

30 As utilized herein, the term "alkyl", alone or in combination, means a straight-chain or branched-chain alkyl radical containing from 1 to about 10, preferably from 1 to about 8, carbon atoms. Examples of such radicals include methyl, ethyl, n-propyl, isopropyl, n-

butyl, isobutyl, sec-butyl, tert-butyl, pentyl, iso-  
amyl, hexyl, octyl and the like. The term "alkoxy",  
alone or in combination, means an alkyl ether radical  
wherein the term alkyl is as defined above. Examples of  
5 suitable alkyl ether radicals include methoxy, ethoxy,  
n-propoxy, isopropoxy, n-butoxy, iso-butoxy, sec-butoxy,  
tert-butoxy and the like. The term "cycloalkyl" means  
an alkyl radical which contains from about 3 to about 8  
carbon atoms and is cyclic. The term "cycloalkylalkyl"  
10 means an alkyl radical as defined above which is  
substituted by a cycloalkyl radical containing from  
about 3 to about 8, preferably from about 3 to about 6,  
carbon atoms. Examples of such cycloalkyl radicals  
include cyclopropyl, cyclobutyl, cyclopentyl, cyclohexyl  
15 and the like. The term "aryl", alone or in combination,  
means a phenyl or naphthyl radical which optionally  
carries one or more substituents selected from alkyl,  
alkoxy, halogen, hydroxy, amino, nitro and the like,  
such as phenyl, p-tolyl, 4-methoxyphenyl, 4-(tert-  
20 butoxy)phenyl, 4-fluorophenyl, 4-chlorophenyl, 4-  
hydroxyphenyl, 1-naphthyl, 2-naphthyl, and the like.  
The term "aralkyl", alone or in combination, means an  
alkyl radical as defined above in which one hydrogen  
atom is replaced by an aryl radical as defined above,  
25 such as benzyl, 2-phenylethyl and the like. The term  
"aralkoxy carbonyl", alone or in combination, means a  
radical of the formula  $-C(O)-O-aralkyl$  in which the term  
"aralkyl" has the significance given above. An example  
of an aralkoxycarbonyl radical is benzyloxycarbonyl.  
30 The term "aryloxy" means a radical of the formula  $aryl-$   
 $o-$  in which the term aryl has the significance given  
above. The term "alkanoyl", alone or in combination,  
means an acyl radical derived from an alkanecarboxylic  
acid, examples of which include acetyl, propionyl,  
35 butyryl, valeryl, 4-methylvaleryl, and the like. The  
term "cycloalkylcarbonyl" means an acyl group derived  
from a monocyclic or bridged cycloalkanecarboxylic acid  
such as cyclopropanecarbonyl, cyclohexanecarbonyl,

adamantanecarbonyl, and the like, or from a benz-fus d monocyclic cycloalkanecarboxylic acid which is optionally substituted by, for example, alkanoylamino, such as 1,2,3,4-tetrahydro-2-naphthoyl, 2-acetamido-  
5 1,2,3,4-tetrahydro-2-naphthoyl. The term "aralkanoyl" means an acyl radical derived from an aryl-substituted alkanecarboxylic acid such as phenylacetyl, 3-phenylpropionyl (hydrocinnamoyl), 4-phenylbutyryl, (2-naphthyl)acetyl, 4-chlorohydrocinnamoyl, 4-aminohydrocinnamoyl, 4-methoxyhydrocinnamoyl, and the like. The term "aroyl" means an acyl radical derived from an aromatic carboxylic acid. Examples of such radicals include aromatic carboxylic acids, an optionally substituted benzoic or naphthoic acid such as  
10 benzoyl, 4-chlorobenzoyl, 4-carboxybenzoyl, 4-(benzyloxycarbonyl)benzoyl, 1-naphthoyl, 2-naphthoyl, 6-carboxy-2 naphthoyl, 6-(benzyloxycarbonyl)-2-naphthoyl, 3-benzyloxy-2-naphthoyl, 3-hydroxy-2-naphthoyl, 3-(benzyloxyformamido)-2-naphthoyl, and the like. The  
20 heterocyclyl or heterocycloalkyl portion of a heterocyclylcarbonyl, heterocyclylloxycarbonyl, heterocyclylalkoxycarbonyl, or heterocyclylalkyl group or the like is a saturated or partially unsaturated monocyclic, bicyclic or tricyclic heterocycle which  
25 contains one or more hetero atoms selected from nitrogen, oxygen and sulphur, which is optionally substituted on one or more carbon atoms by halogen, alkyl, alkoxy, oxo, and the like, and/or on a secondary nitrogen atom (i.e., -NH-) by alkyl, aralkoxycarbonyl, alkanoyl, phenyl or phenylalkyl or on a tertiary  
30 nitrogen atom (i.e. = N-) by oxido and which is attached via a carbon atom. The heteroaryl portion of a heteroaroyl, heteroaryloxycarbonyl, or a heteroaralkoxy carbonyl group or the like is an aromatic monocyclic, bicyclic, or tricyclic heterocycle which contains the  
35 hetero atoms and is optionally substituted as defined above with respect to the definition of heterocyclyl. Examples of such heterocyclyl and heteroaryl groups are

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pyrr lidinyl, piperidinyl, piperazinyl, morpholinyl, thiamorpholinyl, pyrrolyl, imidazolyl ( .g., imidazol 4-yl, 1-benzyloxycarbonylimidazol-4-yl, etc.), pyrazolyl, pyridyl, pyrazinyl, pyrimidinyl, furyl, thienyl, triazolyl, oxazolyl, thiazolyl, indolyl (e.g., 2-indolyl, etc.), quinolinyl, (e.g., 2-quinolinyl, 3-quinolinyl, 1-oxido-2-quinolinyl, etc.), isoquinolinyl (e.g., 1-isoquinolinyl, 3-isoquinolinyl, etc.), tetrahydroquinolinyl (e.g., 1,2,3,4-tetrahydro-2-quinolyl, etc.), 1,2,3,4-tetrahydroisoquinolinyl (e.g., 1,2,3,4-tetrahydro-1-oxo-isoquinolinyl, etc.), quinoxalinyl,  $\beta$ -carbolinyl, 2-benzofurancarbonyl, 1-,2-,4- or 5-benzimidazolyl, and the like. The term "cycloalkylalkoxycarbonyl" means an acyl group derived from a cycloalkylalkoxycarboxylic acid of the formula cycloalkylalkyl-O-COOH wherein cycloalkylalkyl has the significance given above. The term "aryloxyalkanoyl" means an acyl radical of the formula aryl-O-alkanoyl wherein aryl and alkanoyl have the significance given above. The term "heterocyclyloxycarbonyl" means an acyl group derived from heterocyclyl-O-COOH wherein heterocyclyl is as defined above. The term "heterocyclylalkanoyl" is an acyl radical derived from a heterocyclyl-substituted alkane carboxylic acid wherein heterocyclyl has the significance given above. The term "heterocyclylalkoxycarbonyl" means an acyl radical derived from a heterocyclyl-substituted alkane-O-COOH wherein heterocyclyl has the significance given above. The term "heteroaryloxycarbonyl" means an acyl radical derived from a carboxylic acid represented by heteroaryl-O-COOH wherein heteroaryl has the significance given above. The term "aminoalkanoyl" means an acyl group derived from an amino-substituted alkanecarboxylic acid wherein the amino group can be a primary, secondary or tertiary amino group containing substituents selected from hydrogen, and alkyl, aryl, aralkyl, cycloalkyl, cycloalkylalkyl radicals and the like. The term "halogen" means fluorine, chlorine,

-12-

bromine or iodine. The term "leaving group" generally refers to groups readily displaceable by a nucleophile, such as an amine, a thiol or an alcohol nucleophile. Such leaving groups are well known and include

5 carboxylates, N-hydroxysuccinimide, N-hydroxybenzotriazole, halides, triflates, tosylates -OR and -SR and the like. Preferred leaving groups are indicated herein where appropriate.

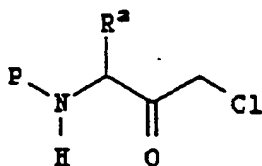
Procedures for preparing the compounds of Formula I

10 are set forth below. It should be noted that the general procedure is shown as it relates to preparation of compounds having the specified stereochemistry, for example, wherein the stereochemistry about the hydroxyl group is designated as (R). However, such procedures

15 are generally applicable, as illustrated in Example 45, to those compounds of opposite configuration, e.g., where the stereochemistry about the hydroxyl group is (S).

#### Preparation of Compounds of Formula II

20 The compounds of the present invention represented by Formula II above can be prepared utilizing the following general procedure. An N-protected chloroketone derivative of an amino acid having the formula:



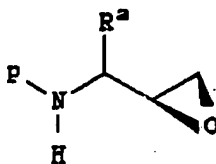
35 wherein P represents an amino protecting group, and R² is as defined above, is reduced to the corresponding alcohol utilizing an appropriate reducing agent. Suitable amino protecting groups are well known in the art and include carbobenzoxy, butyryl, t-butoxycarbonyl, acetyl, benzoyl and the like. A preferred amino

40 protecting group is carbobenzoxy. A preferred N-

-13-

protected chloroketone is N-benzyloxycarbonyl-L-phenylalanine chloromethyl ketone. A preferred reducing agent is sodium borohydride. The reduction reaction is conducted at a temperature of from -10°C to about 25°C, preferably at about 0°C, in a suitable solvent system such as, for example, tetrahydrofuran, and the like. The N-protected chloroketones are commercially available from Bachem, Inc., Torrance, California. Alternatively, the chloroketones can be prepared by the procedure set forth in S. J. Fittkau, J. Prakt. Chem., 315, 1037 (1973), and subsequently N-protected utilizing procedures which are well known in the art.

The resulting alcohol is then reacted, preferably at room temperature, with a suitable base in a suitable solvent system to produce an N-protected amino epoxide of the formula:



wherein P and  $R^2$  are as defined above. Suitable solvent systems for preparing the amino epoxide include ethanol, methanol, isopropanol, tetrahydrofuran, dioxane, and the like including mixtures thereof. Suitable bases for producing the epoxide from the reduced chloroketone include potassium hydroxide, sodium hydroxide, potassium t-butoxide, DBU and the like. A preferred base is potassium hydroxide.

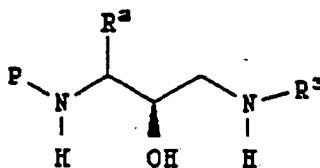
The amino epoxide is then reacted, in a suitable solvent system, with an equal amount, or preferably an excess of, a desired amine of the formula:



wherein  $R^3$  is hydrogen or is as defined above. The reaction can be conducted over a wide range of

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temperatures, e.g., from about 10°C to about 100°C, but is preferably, but not necessarily, conducted at a temperature at which the solvent begins to reflux. Suitable solvent systems include those wherein the solvent is an alcohol, such as methanol, ethanol, isopropanol, and the like, ethers such as tetrahydrofuran, dioxane and the like, and toluene, N,N-dimethylformamide, dimethyl sulfoxide, and mixtures thereof. A preferred solvent is isopropanol. Exemplary amines corresponding to the formula  $R^3NH_2$  include benzyl amine, isobutylamine, n-butyl amine, isopentyl amine, isoamylamine, cyclohexanemethyl amine, naphthylmethyl amine and the like. The resulting product is a 3-(N-protected amino)-3-( $R^2$ )-1-( $NHR^3$ )-propan-2-ol derivative (hereinafter referred to as an amino alcohol) can be represented by the formula:

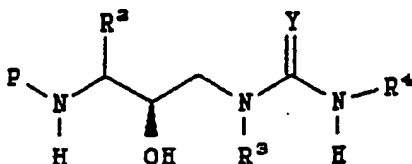


wherein P,  $R^2$  and  $R^3$  are as described above.

For producing compounds of Formula II wherein  $R^5$  is hydrogen, the resulting amino alcohol described above is then reacted, in a suitable solvent system, with an isocyanate of the formula  $R^4NCO$  wherein  $R^4$  is as defined above. Where Y in Formula I above is sulfur, the resulting amino alcohol is reacted with an isothiocyanate of the formula  $R^4NCS$  under similar conditions. Suitable solvent systems include tetrahydrofuran, methylene chloride, and the like and mixtures thereof. The resulting product is a sulfur analog thereof and can be represented by the formula:



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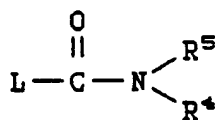


10

wherein P, Y, R<sup>2</sup>, R<sup>3</sup> and R<sup>4</sup> are as defined above. The  
 15 isocyanates of the formula R<sup>4</sup>NCO can be prepared by the  
 reaction of an amine (R<sup>3</sup>NH<sub>2</sub>) with phosgene, triphosgene,  
 carbodiimidazole, or carbonate ((RO)<sub>2</sub>CO) under conditions  
 well-known in the art. The isothiocyanates of the  
 formula R<sub>4</sub>NCS can be prepared by similar procedures,  
 20 e.g., reaction of the amine with thiophosgene, which are  
 also well known in the art. In addition, the  
 isocyanates and isothiocyanates are commercially  
 available from Aldrich Chemical Company.

For preparing compounds of Formula II wherein  
 25 R<sup>5</sup> is other than hydrogen, the resulting amino alcohol  
 described above is then reacted, in a suitable solvent  
 system, with a compound represented by the formula:

30

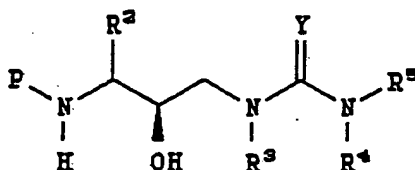


35

wherein R<sup>4</sup> and R<sup>5</sup> are as described above and L represents  
 a leaving group such as a halide, e.g., chloride,  
 imidazole radical, the radical p-NO<sub>2</sub>-(C<sub>6</sub>H<sub>4</sub>)-O-, and the  
 40 like. A preferred compound represented by this formula  
 is a carbamoyl chloride. The corresponding sulfur  
 analogs can be utilized where Y of Formula II is S.

The urea derivative of the amino alcohol and  
 the corresponding sulfur analog can be represented by  
 45 the formula:

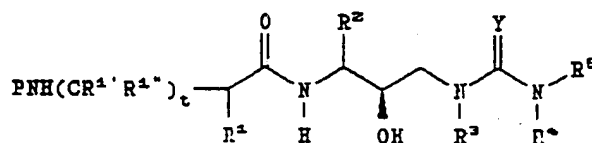
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Following preparation of the urea derivative,  
 or corresponding analogs wherein Y is S, the amino  
 15 protecting group P is removed under conditions which  
 will not affect the remaining portion of the molecule.  
 These methods are well known in the art and include acid  
 hydrolysis, hydrogenolysis and the like. A preferred  
 method involves removal of the protecting group, e.g.,  
 20 removal of a carbobenzoxy group, by hydrogenolysis  
 utilizing palladium on carbon in a suitable solvent  
 system such as an alcohol, acetic acid, and the like or  
 mixtures thereof. Where the protecting group is a t-  
 butoxycarbonyl group, it can be removed utilizing an  
 25 inorganic or organic acid, e.g., HCl or trifluoroacetic  
 acid, in a suitable solvent system, e.g., dioxane or  
 methylene chloride. The resulting product is the amine  
 salt derivative. Following neutralization of the salt,  
 the amine is then reacted with an amino acid or  
 30 corresponding derivative thereof represented by the  
 formula  $(\text{PN}[\text{CR}^{1'} \text{R}^{1''}]^t \text{CH}(\text{R}^1)\text{COOH})$  wherein t,  $\text{R}^1$ ,  $\text{R}^{1'}$  and  $\text{R}^{1''}$   
 are as defined above, to produce the antiviral compounds  
 of the present invention having the formula:

35



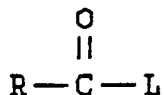
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wherein t, P,  $\text{R}^1$ ,  $\text{R}^{1'}$ ,  $\text{R}^{1''}$ ,  $\text{R}^2$ ,  $\text{R}^3$ ,  $\text{R}^4$ ,  $\text{R}^5$  and Y are as  
 45 defined above. Preferred protecting groups in this

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instance as a benzyloxycarbonyl group or a t-butoxycarbonyl group. Where the amine is reacted with a derivative of an amino acid, e.g., when  $t=1$  and  $R^1$  and  $R^{1''}$  are both H, so that the amino acid is a  $\beta$ -amino acid, such  $\beta$ -amino acids can be prepared according to the procedure set forth in a copending application, U. S. Serial No. 07/345,808. Where  $t$  is 1, one of  $R^1$  and  $R^{1''}$  is H and  $R^1$  is hydrogen so that the amino acid is a homo- $\beta$ -amino acid, such homo- $\beta$ -amino acids can be prepared by the same procedure. Where  $t$  is 0 and  $R^1$  is alkyl, cycloalkyl,  $-\text{CH}_2\text{SO}_2\text{NH}_2$  or an amino acid side chain, such materials are well known and many are commercially available from Sigma-Aldrich.

The N-protecting group can be subsequently removed, if desired, utilizing the procedures described above, and then reacted with a carboxylate represented by the formula:



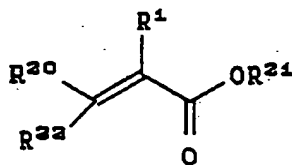
wherein R is as defined above and L is an appropriate leaving group such as a halide. Preferably, where  $R^1$  is a side chain of a naturally occurring  $\alpha$ -amino acid, R is a 2-quinoline carbonyl group derived from N-hydroxysuccinimide-2-quinoline carboxylate, i.e., L is hydroxy succinimide. A solution of the free amine (or amine acetate salt) and about 1.0 equivalent of the carboxylate are mixed in an appropriate solvent system and optionally treated with up to five equivalents of a base such as, for example, N-methylmorpholine, at about room temperature. Appropriate solvent systems include tetrahydrofuran, methylene chloride or N,N-dimethylformamide, and the like, including mixtures thereof.

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Preparation of Compounds of Formula III

A mercaptan of the formula  $R'SH$  is reacted with a substituted methacrylate of the formula:

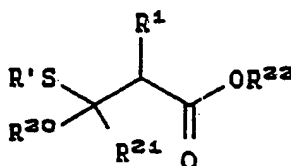
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by way of a Michael Addition. The Michael Addition is conducted in a suitable solvent and in the presence of a suitable base, to produce the corresponding thiol derivative represented by the formula:

20



25

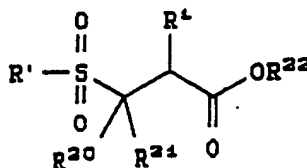
wherein  $R'$  and  $R^1$  represent radicals defined above;  $R^{20}$  and  $R^{21}$  represent hydrogen and radicals as defined for  $R^1$ ; and  $R^{22}$  represents radicals as defined by  $R^3$ . Suitable solvents in which the Michael Addition can be conducted include alcohols such as, for example, methanol, ethanol, butanol and the like, as well as ethers, e.g., THF, and acetonitrile, DMF, DMSO, and the like, including mixtures thereof. Suitable bases include Group I metal alkoxides such as, for example sodium methoxide, sodium ethoxide, sodium butoxide and the like as well as Group I metal hydrides, such as sodium hydride, including mixtures thereof.

40

The thiol derivative is converted into the corresponding sulfone of the formula:

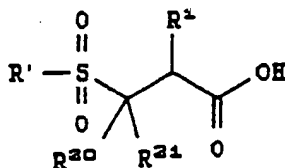
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10 by oxidizing the thiol derivative with a suitable oxidation agent in a suitable solvent. Suitable oxidation agents include, for example, hydrogen peroxide, sodium meta-perborate, oxone (potassium peroxy monosulfate), meta-chloroperoxybenzoic acid, and the  
15 like, including mixtures thereof. Suitable solvents include acetic acid (for sodium meta-perborate) and, for other peracids, ethers such as THF and dioxane, and acetonitrile, DMF and the like, including mixtures thereof.

20 The sulfone is then converted to the corresponding free acid of the formula:



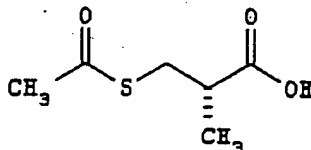
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utilizing a suitable base, e.g., lithium hydroxide, sodium hydroxide, and the like, including mixtures  
35 thereof, in a suitable solvent, such as, for example, THF, acetonitrile, DMF, DMSO, methylene chloride and the like, including mixtures thereof.

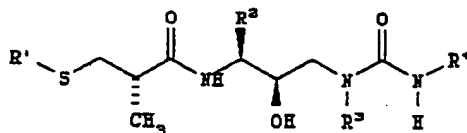
The free acid is then coupled, utilizing, as described above, procedures well known in the art, to  
40 the urea derivative, or analog thereof, of an amino alcohol which is described above for the preparation of compounds of Formula II. The resulting product is a compound represented by Formula III.

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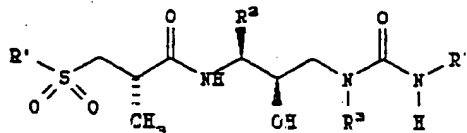
Alternatively, one can couple the urea  
isoster to the commercially available acid,



remove the thioacetyl group with a suitable base, such  
as hydroxide, or an amine, such as ammonia, and then  
react the resulting thiol with an alkylating agent, such  
as an alkyl halide, tosylate or mesylate to afford  
compounds at the following structure:

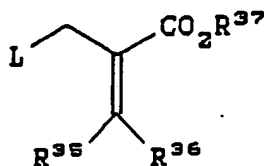


The sulfur can then be oxidized to the  
corresponding sulfone using suitable oxidizing agents,  
as described above, to afford the desired compounds of  
the following structure:

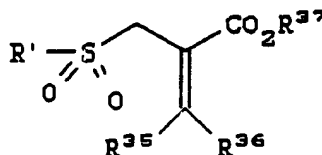


Alternatively, to prepare compounds of Formula III, a  
substituted methacrylate of the formula:

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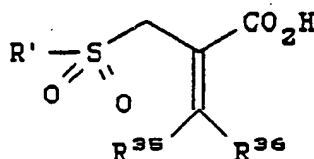


5  
 10 wherein L represents a leaving group as previously defined,  $\text{R}^{35}$  and  $\text{R}^{36}$  represent hydrogen and radicals as defined for  $\text{R}^1$ ; and  $\text{R}^{37}$  represents alkyl, aralkyl, cycloalkyl and cycloalkylalkyl radicals,  
 is reacted with a suitable sulfonating agent, such as,  
 15 for example, a sulfinic acid represented by the formula  $\text{R}'\text{SO}_2\text{M}$ , wherein  $\text{R}'$  represents radicals as defined above and M represents a metal adapted to form a salt of the acid, e.g., sodium, to produce the corresponding sulfone represented by the formula:



30

wherein  $\text{R}'$ ,  $\text{R}^{35}$ ,  $\text{R}^{36}$  and  $\text{R}^{37}$  are as defined above. The sulfone is then hydrolyzed in the presence of a suitable  
 35 base, such as lithium hydroxide, sodium hydroxide and the like, to the compound represented by the formula:



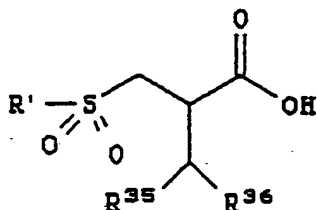
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wherein  $\text{R}'$ ,  $\text{R}^{35}$  and  $\text{R}^{36}$  represent radicals as defined above. The resulting compound is then asymmetrically hydrogenated utilizing an asymmetric hydrogenation

catalyst such as, for example, a ruthenium-BINAP complex, to produce the reduced product, substantially enriched in the more active isomer, represented by the formula:

5

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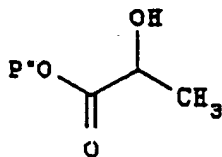
15 wherein  $R'$ ,  $R^{35}$  and  $R^{36}$  represent radicals as defined above. Where the more active isomer has the R-stereochemistry, a  $Ru(R\text{-BINAP})$  asymmetric hydrogenation catalyst can be utilized. Conversely, where the more active isomer has the S-stereochemistry, a  $Ru(S\text{-BINAP})$  catalyst can be utilized. Where both isomers are active, or where it is desired to have a mixture of the two diastereomers, a hydrogenation catalyst such as platinum, or palladium, on carbon can be utilized to reduce the above compound. The reduced compound is then coupled to the urea isostere, as described above, to produce compounds of Formula III.

#### Preparation of Compounds of Formula IV

To produce compounds of Formula IV, starting with a lactate of the formula:

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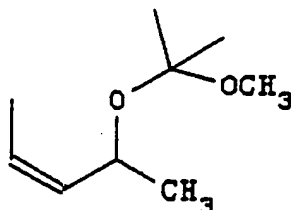
40 wherein  $P''$  represents alkyl radicals, such as, for example, ethyl, methyl, benzyl and the like. The hydroxyl group of the lactate is protected as its ketal by reaction in a suitable solvent system with methyl



isopropenyl ether (1,2-methoxypropene) in the presence of a suitable acid. Suitable solvent systems include methylene chloride, tetrahydrofuran and the like as well as mixtures thereof. Suitable acids include  $\text{POCl}_3$  and the like. It should be noted that well-known groups other than methyl isopropenyl ether can be utilized to form the ketal. The ketal is then reduced with diisobutylaluminum hydride (DIBAL) at  $-78^\circ\text{C}$  to produce the corresponding aldehyde which is then treated with ethylidene triphenylphosphorane (Wittig reaction) to produce a compound represented by the formula:

15

20

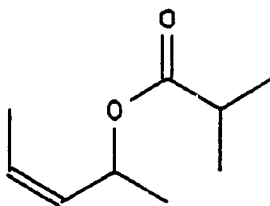


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The ketal protecting group is then removed utilizing procedures well-known in the art such as by mild acid hydrolysis. The resulting compound is then esterified with isobutyryl chloride to produce a compound of the formula:

35

40



45

This compound is then treated with lithium diisopropyl amide at  $-78^\circ\text{C}$  followed by warming of the reaction mixture to room temperature to effect a Claisen

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rearrangement ([3,3]) to produce the corresponding acid represented by the formula:



Treatment of the acid with benzyl bromide in the presence of a tertiary amine base, e.g., DBU, produces the corresponding ester which is then cleaved oxidatively to give a trisubstituted succinic acid:

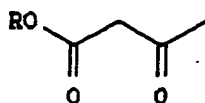


The trisubstituted succinic acid is then coupled to the urea isostere as described above. To produce the free acid, the benzyl ester is removed by hydrogenolysis to produce the corresponding acid. The acid can then be converted to the primary amide by methods well-known in the art.

An alternative method for preparing trisubstituted succinic acids involves reacting an ester of acetoacetic acid represented by the formula:

45

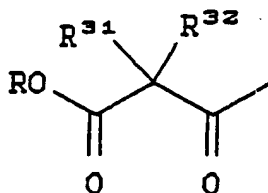
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where R is a suitable protecting group, such as methyl, ethyl, benzyl or t-butyl with sodium hydride and a hydrocarbyl halide ( $R^{31}X$  or  $R^{32}X$ ) in a suitable solvent, e.g., THF, to produce the corresponding disubstituted derivative represented by the formula:

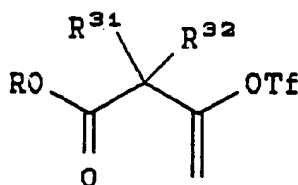
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This disubstituted acetoacetic acid derivative is then treated with lithium diisopropyl amide at about  $-10^{\circ}\text{C}$  and in the presence of  $\text{PhN}(\text{triflate})_2$  to produce a vinyl triflate of the formula:

30



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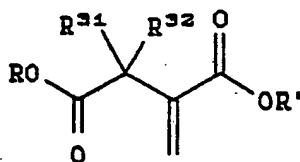
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The vinyl triflate is then carbonylated utilizing a palladium catalyst, e.g.,  $\text{Pd}_2(\text{OAc})_2(\text{Ph}_3\text{P})$ , in the presence of an alcohol ( $R''\text{OH}$ ) or water ( $R''=\text{H}$ ) and a base, e.g., triethylamine, in a suitable solvent such as DMF, to produce the olefinic ester or acid of the formula:

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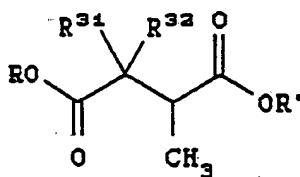
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The olefin can then be subsequently asymmetrically hydrogenated, as described above, to produce a trisubstituted succinic acid derivative of the formula:

15



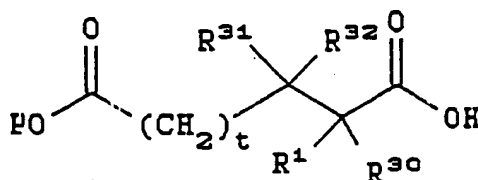
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25 If R" is not H, R" can be removed by either hydrolysis, acidolysis, or hydrogenolysis, to afford the corresponding acid, which is then coupled to the urea isostere as described above and then, optionally, the R group removed to produce the corresponding acid, and  
30 optionally, converted to the amide.

Alternatively, one can react the urea isostere with either a suitably monoprotected succinic acid or glutaric acid of the following structure;

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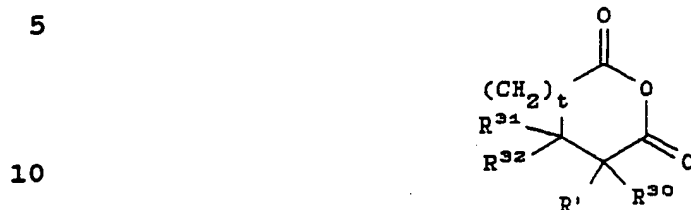


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followed by removal of the protecting group and conversion of the resulting acid to an amide. One can also react an anhydride of the following structure;



15 with the urea isostere and then separate any isomers or convert the resulting acid to an amide and then separate any isomers.

It is contemplated that for preparing compounds of the Formulas having  $R^6$ , the compounds can be prepared following the procedure set forth above and, prior to coupling the urea derivative or analog thereof to the amino acid  $PNH(CH_2)_tCH(R^1)COOH$ , carried through a procedure referred to in the art as reductive amination. Thus, a sodium cyanoborohydride and an appropriate aldehyde  $R^6C(O)H$  or ketone  $R^6C(O)R^6$  can be reacted with the urea derivative compound or appropriate analog at room temperature in order to reductively aminate any of the compounds of Formulas I-IV. It is also contemplated that where  $R^3$  of the amino alcohol intermediate is hydrogen, the inhibitor compounds can be prepared through reductive amination of the final product of the reaction between the amino alcohol and the amine or at any other stage of the synthesis for preparing the inhibitor compounds.

35 Contemplated equivalents of the general formulas set forth above for the antiviral compounds and derivatives as well as the intermediates are compounds otherwise corresponding thereto and having the same general properties wherein one or more of the various R groups are simple variations of the substituents as defined therein, e.g., wherein R is a higher alkyl group than that indicated. In addition, where a substituent

40

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is designated as, or can be, a hydrogen, the exact chemical nature of a substituent which is other than hydrogen at that position, e.g., a hydrocarbyl radical or a halogen, hydroxy, amino and the like functional group, is not critical so long as it does not adversely affect the overall activity and/or synthesis procedure.

The chemical reactions described above are generally disclosed in terms of their broadest application to the preparation of the compounds of this invention. Occasionally, the reactions may not be applicable as described to each compound included within the disclosed scope. The compounds for which this occurs will be readily recognized by those skilled in the art. In all such cases, either the reactions can be successfully performed by conventional modifications known to those skilled in the art, e.g., by appropriate protection of interfering groups, by changing to alternative conventional reagents, by routine modification of reaction conditions, and the like, or other reactions disclosed herein or otherwise conventional, will be applicable to the preparation of the corresponding compounds of this invention. In all preparative methods, all starting materials are known or readily preparable from known starting materials.

Without further elaboration, it is believed that one skilled in the art can, using the preceding description, utilize the present invention to its fullest extent. The following preferred specific embodiments are, therefore, to be construed as merely illustrative, and not limitative of the remainder of the disclosure in any way whatsoever.

All reagents were used as received without purification. All proton and carbon NMR spectra were obtained on either a Varian VXR-300 or VXR-400 nuclear magnetic resonance spectrometer.

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Example 1

Preparation of [1S-[1R\*(R\*), 2S\*]]- N'[3-[[[(1,1-  
dimethylethyl)amino]carbonyl](2-methylpropyl)amino] -2-  
hydroxy-1-(phenylmethyl)propyl]-2-[(2-  
5 quinolinylcarbonyl)amino]-butanediamide

Part A:

To a solution of 75.0g (0.226 mol) of N-benzyloxycarbonyl-L-phenylalanine chloromethyl ketone in a mixture of 807 mL of methanol and 807 mL of  
10 tetrahydrofuran at -2°C, was added 13.17g (0.348 mol, 1.54 equiv.) of solid sodium borohydride over one hundred minutes. The solvents were removed under reduced pressure at 40°C and the residue dissolved in ethyl acetate (approx. 1L). The solution was washed  
15 sequentially with 1M potassium hydrogen sulfate, saturated sodium bicarbonate and then saturated sodium chloride solutions. After drying over anhydrous magnesium sulfate and filtering, the solution was removed under reduced pressure. To the resulting oil  
20 was added hexane (approx. 1L) and the mixture warmed to 60°C with swirling. After cooling to room temperature, the solids were collected and washed with 2L of hexane. The resulting solid was recrystallized from hot ethyl acetate and hexane to afford 32.3g (43% yield) of N-  
25 benzyloxycarbonyl-3(S)-amino-1-chloro-4-phenyl-2(S)-butanol, mp 150-151°C and  $M+Li^+ = 340$ .

Part B:

To a solution of 6.52g (0.116 mol, 1.2 equiv.) of potassium hydroxide in 968 mL of absolute ethanol at  
30 room temperature, was added 32.3g (0.097 mol) of N-CBZ-3(S)-amino-1-chloro-4-phenyl-2(S)-butanol. After stirring for fifteen minutes, the solvent was removed under reduced pressure and the solids dissolved in methylene chloride. After washing with water, drying  
35 over magnesium sulfate, filtering and stripping, one obtains 27.9g of a white solid. Recrystallization from hot ethyl acetate and hexane afforded 22.3g (77% yield)

-30-

of N-benzyloxycarbonyl-3(S)-amino-1,2(S)-epoxy-4-phenylbutane, mp 102-103°C and  $MH^+$  298.

Part C:

A solution of N-benzyloxycarbonyl 3(S)-amino-1,2-(S)-epoxy-4-phenylbutane (1.00g, 3.36 mmol) and isobutylamine (4.90g, 67.2 mmol, 20 equiv.) in 10 mL of isopropyl alcohol was heated to reflux for 1.5 hours. The solution was cooled to room temperature, concentrated *in vacuo* and then poured into 100 mL of stirring hexane whereupon the product crystallized from solution. The product was isolated by filtration and air dried to give 1.18g, 95% of N=[3(S)-phenylmethylcarbamoyl]amino-2(R)-hydroxy-4-phenylbutyl]N-[(2-methylpropyl)]amine mp 108.0-109.5°C,  $MH^+$  m/z = 371.

Part D:

A solution of [2(R), 3(S)]-N-[3-(phenylmethylcarbamoyl)amino]-2-hydroxy-4-phenylbutyl]N-[(2-methylpropyl)]amine in 10 ml of tetrahydrofuran was treated with tert-butylisocyanate (267 mg, 2.70 mmol) at room temperature for 5 minutes. The solvent was removed *in vacuo* and replaced with ethyl acetate. The ethyl acetate solution was washed with 5% citric acid, water, and brine, dried over anhydrous  $MgSO_4$ , filtered and concentrated *in vacuo* to give 1.19g, 97% of [2(R), 3(S)]-N-[3-(phenylmethylcarbamoyl)amino]-2-hydroxy-4-phenyl]-1-[(2-methylpropyl)]amino-2-(1,1-dimethyl)amino]carbonyl]butane,  $MH^+$  m/z = 470.

Part E:

A solution of (1.00g, 2.21 mmol) [2(R), 3(S)]-N-[3-(phenylmethylcarbamoyl)amino]-2-hydroxy-4-phenyl]-1-[(2-methylpropyl)]amino-1-(1,1-dimethylethyl)amino]carbonyl]butane in 20 mL of methanol was hydrogenated over 10% palladium-on-carbon for 4 hours to give [2(R), 3(S)]-N-[3-amino]-2-hydroxy-4-phenyl]-1-[(2-methylpropyl)]amino-1-(1,1-dimethylethyl)amino]carbonyl]butane 720 mg, 97%.



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Part F:

A solution of *N*-Cbz-L-asparagine (602mg, 2.26 mmol) and *N*-hydroxybenzotriazole (493 mg, 3.22 mmol) in 2mL of dimethylformamide was cooled to 0°C and treated with EDC (473 mg, 2.47 mmol). The solution was allowed to stir at 0°C for 20 minutes and then treated with [2(R), 3(S)]-*N*-[[3-amino]-2-hydroxy-4-phenyl]-1-[(2-methylpropyl)amino]-1-(1,1-dimethylethyl)amino]carbonyl]butane (720 mg, 2.15 mmol) in 1mL of dimethylformamide. The solution was allowed to warm to room temperature and held at this temperature for 7 hours. The reaction mixture was then poured into 100 mL of 60% saturated aqueous sodium bicarbonate whereupon a white precipitate formed that was isolated by filtration. The filter cake was washed with water, 5% aqueous citric acid, water and then dried in vacuo to give 1.04g, 83% of [1S-[1R\*(R\*), 2S\*]]-N<sup>1</sup>[3-[[[(1,1-dimethylethyl)amino]carbonyl](2-methylpropyl)amino], mp. 164.0-166.5°C, MH<sup>+</sup> m/z = 584.

20 Part G.

A solution of [1S-[1R\*(R\*), 2S\*]]-N<sup>1</sup>[3-[[[(1,1-dimethylethyl)amino]carbonyl](2-methylpropyl)amino]-2-hydroxy-1-(phenylmethyl)propyl]-2-[(phenylmethylcarbonyl)amino]-butanediamide (1.00g, 1.72 mmol) in 10 mL of methanol was hydrogenated over 10% palladium-on-carbon for 4 hours to give [1S-[1R\*(R\*), 2S\*]]-N<sup>1</sup>[3-[[[(1,1-dimethylethyl)amino]carbonyl](2-methylpropyl)amino]-2-hydroxy-1-(phenylmethyl)propyl]-2-amino]-butanediamide, 784mg, 99%.

Part H:

A mixture of [1S-[1R\*(R\*), 2S\*]]-N<sup>1</sup>[3-[[[(1,1-dimethylethyl)amino]carbonyl](2-methylpropyl)amino]-2-hydroxy-1-(phenylmethyl)propyl]-2-amino]-butanediamide, (784 mg, 1.70 mmol), 2-quinoline carboxylic acid *N*-hydroxysuccinimide ester (459 mg, 1.70 mmol), *N*-methylmorpholine (343 mg, 3.40 mmol) in 5 mL of dichloromethane was stirred at room temperature for 15

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minutes. The solvent was removed in vacuo and replaced with ethyl acetate and the solution washed with 5% aqueous citric acid, saturated aqueous sodium bicarbonate, brine, dried over anhydrous  $\text{MgSO}_4$ , filtered and concentrated in vacuo. The crude product was recrystallized from acetone/hexane to give 790 mg, 77% of [1S-[1R\*(R\*), 2S\*]]-N<sup>1</sup>[3-[[[(1,1-dimethylethyl)amino]carbonyl](2-methylpropyl)amino]-2-hydroxy-1-(phenylmethyl)propyl]-2-[(2-quinolinylcarbonyl)amino]-butanediamide, mp 107.0-109.8°C,  $\text{MH}^+$  = 605.

#### Example 2

The procedure described in Example 1, part C-H, was used to prepare [1S-[1R\*(R\*), 2S\*]]-N<sup>1</sup>[3-[[[(1,1-dimethylethyl)amino]carbonyl](3-methylbutyl)amino]-2-hydroxy-1-(phenylmethyl)propyl]-2-[(2-quinolinylcarbonyl)amino]-butanediamide.

- a) From the reaction of 1.06g (3.56mmol) of N-benzyloxycarbonyl 3(S)-amino-1,2-(S)-epoxy-4-phenylbutane and 6.25g (71.7mmol) of isoamylamine, one obtains 1.27g (92%) of [2(R), 3(S)]-N-[[3-(phenylmethylcarbonyl)amino]-2-hydroxy-4-phenylbutyl]N-[(3-methylbutyl)amine], mp 130-132°C and  $\text{MH}^+$  385. This amine (400mg, 1.04mmol) was then reacted with tert-butylisocyanate (110mg, 1.11mmol) to afford 500mg (100%) of [2(R), 3(S)]-N-[[3-(phenylmethylcarbonyl)amino]-2-hydroxy-4-phenyl]-1-[(3-methylbutyl)amino]-1-(1,1-dimethylethyl)amino]carbonyl]butane; as an oil,  $\text{MH}^+$  484.
- b) The CBZ protected compound (530mg, 1.10mmol) was then deprotected by hydrogenation over 10% palladium-on-carbon and the resulting free amine coupled with N-CBZ-L-asparagine (377mg, 1.42mmol) in the presence of N-hydroxybenzotriazole (290mg, 2.15mmol) and EDC (300mg, 1.56mmol) to yield 430mg (53%) of [1S-[1R\*(R\*), 2S\*]]-N<sup>1</sup>[3-[[[(1,1-dimethylethyl)amino]carbonyl](3-methylbutyl)amino]-

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2-hydroxy-1-(phenylmethyl)propyl]-2-  
[(phenylmethylcarbamoyl)amino]-butanediamide, mp  
148-151°C (dec) and  $MH^+$  598. This compound (370mg,  
0.619mmol) was then deprotected by hydrogenation  
5 over 10% palladium-on-carbon and the resulting free  
amine coupled with 2-quinolinecarboxylic acid N-  
hydroxy-succinimide ester (193mg, 0.714mmol), in the  
presence of N-methylmorpholine, to afford 310mg  
(70%) of pure [1S-[1R\*(R\*), 2S\*]]- N<sup>1</sup>[3-[[[(1,1-  
10 dimethylethyl)amino]carbonyl](3-methylbutyl)amino]-  
2-hydroxy-1-(phenylmethyl)propyl]-2-[(2-  
quinolinylcarbonyl)amino]-butanediamide; mp 93.5-  
95.5°C and  $MH^+$  619.

### Example 3

15 The procedure described in Example 1, part C-  
H, was used to prepare [1S-[1R\*(R\*), 2S\*]]- N<sup>1</sup>[3-[[[(1,1-  
dimethylethyl)amino]carbonyl]2-naphthylmethyl)amino]-2-  
hydroxy-1-(phenylmethyl)propyl]-2-[(2-  
quinolinylcarbonyl)amino]-butanediamide.

20 a) From the reaction of 1.80g (6.05mmol) of N-  
benzyloxycarbonyl 3(S)-amino-1,2-(S)-epoxy-4-  
phenylbutane and 1.15g (7.31mmol) of 2-  
(aminomethyl)naphthalene, one obtains 2.11g (77%) of  
[2(R), 3(S)]-N-[[3-(phenylmethylcarbamoyl)amino]-2-  
25 hydroxy-4-phenylbutyl]N-[(2-naphthylmethyl)]amine,  $MH^+$   
455. This amine (366.8mg, 0.807mmol) was then  
reacted with tert-butylisocyanate (66.4mg, 0.67mmol)  
to afford 350.0mg (94%) of [2(R), 3(S)]-N-[[3-  
(phenylmethylcarbamoyl)amino]-2-hydroxy-4-phenyl]-  
30 1-[(2-naphthylmethyl)]amino-1-(1,1-  
dimethylethyl)amino]carbonyl]butane; as an oil,  $MH^+$   
554.

b) The CBZ protected compound (330mg, 0.596mmol) was  
then deprotected by hydrogenation over 10%  
35 palladium-on-carbon and the resulting free amine  
coupled with N-CBZ-L-asparagine (165.1mg, 0.62mmol)  
in the presence of N-hydroxybenzotriazole (142.3mg,  
0.93mmol) and EDC (130.7mg, 0.68mmol) to yield

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161.7mg (41%) of [1S-[1R\*(R\*), 2S\*]]- N<sup>1</sup>[3-[[[(1,1-dimethylethyl)amino]carbonyl](2-naphthylmethyl)amino]-2-hydroxy-1-(phenylmethyl)propyl]-2-  
5 [(phenylmethylcarbamoyl)amino]-butanediamide; mp 151-152°C (dec) and MH<sup>+</sup> 668. This compound (91.0mg, 0.136mmol) was then deprotected by hydrogenation over 10% palladium-on-carbon and the resulting free amine coupled with 2-quinolinecarboxylic acid N-  
10 hydroxysuccinimide ester (36.8mg, 0.136mmol), in the presence of N-methylmorpholine, to afford 65.8mg (70%) of pure [1S-[1R\*(R\*), 2S\*]]- N<sup>1</sup>[3-[[[(1,1-dimethylethyl)amino]carbonyl](2-naphthylmethyl)amino]-2-hydroxy-1-(phenylmethyl)propyl]-2-[(2-  
15 quinolinylnylcarbonyl)amino]-butanediamide; mp 119-120°C and MH<sup>+</sup> 689.

#### Example 4

The procedure described in Example 1, part C-  
20 H, was used to prepare [1S-[1R\*(R\*), 2S\*]]- N<sup>1</sup>[3-[[[(1,1-dimethylethyl)amino]carbonyl](2-phenylethyl)amino]-2-hydroxy-1-(phenylmethyl)propyl]-2-[(2-quinolinylnylcarbonyl)amino]-butanediamide.

a) From the reaction of 1.00g (3.36mmol) of N-  
25 benzyloxycarbonyl 3(S)-amino-1,2-(S)-epoxy-4-phenylbutane and 8.19g (67.0mmol) of 2-phenethylamine, one obtains 1.10g (79%) of [2(R), 3(S)]-N-[[3-(phenylmethylcarbamoyl)amino]-2-hydroxy-4-phenylbutyl]N-[(2-phenylethyl)]amine, mp 137-138°C and MH<sup>+</sup> 419. This amine (750mg, 1.79mmol) was then  
30 reacted with tert-butylisocyanate (178mg, 1.79mmol) to afford 897mg (97%) of [2(R), 3(S)]-N-[[3-(phenylmethylcarbamoyl)amino]-2-hydroxy-4-phenyl]-1-[(2-phenylethyl)]amino-1-(1,1-  
35 dimethylethyl)amino]carbonyl]butane; as an oil, MH<sup>+</sup> 518.

b) The CBZ protected compound (897mg, 1.73mmol) was then deprotected by hydrogenation over 10%

palladium-on-carbon and the resulting free amine coupled with N-CBZ-L-asparagine (620.7mg, 2.33mmol) in the presence of N-hydroxybenzotriazole (509.5mg, 3.33mmol) and EDC (488.0mg, 2.55mmol) to yield 1.00g (92%) of [1S-[1R\*(R\*), 2S\*]]- N<sup>1</sup>[3[[[(1,1-dimethylethyl)amino]carbonyl](2-phenylethyl)amino]-2-hydroxy-1-(phenylmethyl)propyl]-2-[(phenylmethylcarbamoyl)amino]-butanediamide; mp 145°C (dec) and MH<sup>+</sup> 632. This compound (860mg, 1.36mmol) was then deprotected by hydrogenation over 10% palladium-on-carbon and the resulting free amine coupled with 2-quinolinecarboxylic acid N-hydroxysuccinimide ester (338mg, 1.25mmol), in the presence of N-methylmorpholine, to afford 450.4mg (55%) of pure [1S-[1R\*(R\*), 2S\*]]- N<sup>1</sup>[3[[[(1,1-dimethylethyl)amino]carbonyl](2-phenylethyl)amino]-2-hydroxy-1-(phenylmethyl)propyl]-2-[(2-quinolinylcarbonyl)amino]-butanediamide; mp 139-140°C and MH<sup>+</sup> 653.

#### 20                      Example 5

The procedure described in Example 1, part C-H, was used to prepare [1S-[1R\*(R\*), 2S\*]]- N<sup>1</sup>[3-[[[(1,1-dimethylethyl)amino]carbonyl](2,2-dimethylpropyl)amino]-2-hydroxy-1-(phenylmethyl)propyl]-2-[(2-quinolinylcarbonyl)amino]-butanediamide.

25                      a) From the reaction of 1.00g (3.36mmol) of N-benzyloxycarbonyl 3(S)-amino-1,2-(S)-epoxy-4-phenylbutane and 7.9mL (approx. 67mmol) of neopentyl amine, one obtains 0.69g (49%) of [2(R), 3(S)]-N-[[3-(phenylmethylcarbamoyl)amino]-2-hydroxy-4-phenylbutyl]N-[(2,2-dimethylpropyl)amine, MH<sup>+</sup> 385. This amine (686mg, 1.78mmol) was then reacted with tert-butylisocyanate (180mg, 1.78mmol) to afford 860mg (100%) of [2(R), 3(S)]-N-[[3-(phenylmethylcarbamoyl)amino]-2-hydroxy-4-phenyl]-1-[(2,2-dimethylpropyl)amino]-1-(1,1-dimethyl thyl)amino]carbonyl]butane; MH<sup>+</sup> 484.

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- b) The CBZ protected compound (860mg, 1.78mmol) was then d protected by hydrogenation over 10% palladium-on-carbon and the resulting free amine coupled with N-CBZ-L-asparagine (471mg, 1.77mmol) in the presence of N-hydroxybenzotriazole (406mg, 2.66mmol) and EDC (374mg, 1.95mmol) to yield 326mg (34%) of [1S-[R\*(R\*), 2S\*]]- N<sup>1</sup>[3-[[[(1,1-dimethylethyl)amino]carbonyl](2,2-dimethylpropyl)amino]-2-hydroxy-1-(phenylmethyl)propyl]-2-[(phenylmethylcarbamoyl)amino]-butanediamide; mp 177-178°C and MH<sup>+</sup> 598. This compound (245mg, 0.41mmol) was then deprotected by hydrogenation over 10% palladium-on-carbon and the resulting free amine coupled with 2-quinolinecarboxylic acid N-hydroxy-succinimide ester (111mg, 0.41mmol), in the presence of N-methylmorpholine, to afford 150mg (59%) of pure [1S-[R\*(R\*), 2S\*]]- N<sup>1</sup>[3-[[[(1,1-dimethylethyl)amino]carbonyl](2,2-dimethylpropyl)amino]-2-hydroxy-1-(phenylmethyl)propyl]-2-[(2-quinolinylcarbonyl)amino]-butanediamide; mp 115-117°C and MH<sup>+</sup> 619.

#### Example 6

- The procedure described in Example 1, part C-H, was used to prepare [1S-[R\*(R\*), 2S\*]]- N<sup>1</sup>[3-[[[(1,1-dimethylethyl)amino]carbonyl](4-methoxyphenylmethyl)amino]-2-hydroxy-1-(phenylmethyl)propyl]-2-[(2-quinolinylcarbonyl)amino]-butanediamide;
- a) From the reaction of 1.00g (3.36mmol) of N-benzyloxycarbonyl 3(S)-amino-1,2-(S)-epoxy-4-phenylbutane and 9.2g (67mmol) of 4-methoxybenzyl amine, one obtains 1.12g (76%) of [2(R), 3(S)]-N-[[3-(phenylmethylcarbamoyl)amino]-2-hydroxy-4-phenylbutyl]N-[(4-methoxyphenylmethyl)amine, MH<sup>+</sup> 435. This amine (1.12g, 2.58mmol) was then reacted with tert-butylisocyanate (260mg, 2.58mmol) to

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afford 1.35g (98%) of [2(R), 3(S)]-N-[[3-(phenylmethylcarbamoyl)amino]-2-hydroxy-4-phenyl]-1-[(4-methoxyphenylmethyl)amino]-1-(1,1-dimethylethyl)amino]carbonyl]butane;  $MH^+$  534.

- 5 b) The CBZ protected compound (1.35g, 2.53mmol) was then deprotected by hydrogenation over 10% palladium-on-carbon and the resulting free amine coupled with N-CBZ-L-asparagine (684mg, 2.57mmol) in the presence of N-hydroxybenzotriazole (590mg, 3.85mmol) and EDC (543mg, 2.83mmol) to yield 442mg (29%) of [1S-[1R\*(R\*), 2S\*]]-N<sup>1</sup>[3-[[[(1,1-dimethylethyl)amino]carbonyl](4-methoxyphenylmethyl)amino]-2-hydroxy-1-(phenylmethyl)propyl]-2-[phenylmethylcarbamoyl]amino]-butanediamide; mp 15 175°C (dec) and  $MH^+$  648. This compound (345mg, 0.53mmol) was then deprotected by hydrogenation over 10% palladium-on-carbon and the resulting free amine coupled with 2-quinolinecarboxylic acid N-hydroxy-succinimide ester (118mg, 0.44mmol), in the presence of N-methylmorpholine, to afford 108mg (31%) of pure 20 [1S-[1R\*(R\*), 2S\*]]-N<sup>1</sup>[3-[[[(1,1-dimethylethyl)amino]carbonyl](4-methoxyphenylmethyl)amino]-2-hydroxy-1-(phenylmethyl)propyl]-2-[(2-quinolinylcarbonyl)amino]-butanediamide; mp 220°C 25 (dec) and  $MLi^+$  675.

#### Example 7

The procedure described in Example 1, part C-30 H, was used to prepare [1S-[1R\*(R\*), 2S\*]]-N<sup>1</sup>[3-[[[(1,1-dimethylethyl)amino]carbonyl](n-butyl)amino]-2-hydroxy-1-(phenylmethyl)propyl]-2-[(2-quinolinylcarbonyl)amino]-butanediamide.

- a) From the reaction of 1.48g (5.0mmol) of N-35 b nzyloxycarbonyl 3(S)-amino-1,2-(S)-epoxy-4-phenylbutane and 7.314g (100.0mmol) of n-butyl amine, one obtains 1.50g (80%) of [2(R), 3(S)]-N-[[3-(phenylmethylcarbamoyl)amino]-2-hydroxy-4-

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- ph nylbutyl]N-[n-butyl]amine. This amine (1.48g, 4.0mmol) was then reacted with tert-butylisocyanate (396mg, 4.0mmol) to afford 1.87g (100%) of [2(R), 3(S)]-N-[[3-(phenylmethylcarbamoyl)amino]-2-hydroxy-4-phenyl]-1-[(n-butyl)amino]-1-(1,1-dimethylethyl)amino]carbonyl] butane as an oil.
- b) The CBZ protected compound (1.87g, 4.0mmol) was then deprotected by hydrogenation over 10% palladium-on-carbon and the resulting free amine coupled with N-CBZ-L-asparagine (1.05g, 3.96mmol) in the presence of N-hydroxybenzotriazole (535mg, 7.9mmol) and EDC (759mg, 3.96mmol) to yield 1.75g (76%) of [1S-[1R\*(R\*), 2S\*]]-N<sup>1</sup>[3-[[[(1,1-dimethylethyl)amino]carbonyl](n-butyl)amino]-2-hydroxy-1-(phenylmethyl)propyl]-2-[(phenylmethylcarbamoyl)amino]-butanediamide; mp 166-167°C and MH<sup>+</sup> 584.

#### Example 8

- The procedure described in Example 1, part C-H, was used to prepare [1S-[1R\*(R\*), 2S\*]]-N<sup>1</sup>[3-[[[(1,1-dimethylethyl)amino]carbonyl](phenylmethyl)amino]-2-hydroxy-1-(phenylmethyl)propyl]-2-[(2-quinolinylcarbonyl)amino]-butanediamide.
- a) From the reaction of 1.48g (5.0mmol) of N-benzyloxycarbonyl 3(S)-amino-1,2-(S)-epoxy-4-phenylbutane and 10.68g (100.0mmol) of benzyl amine, one obtains 1.88g (95%) of [2(R), 3(S)]-N-[[3-(phenylmethylcarbamoyl)amino]-2-hydroxy-4-phenylbutyl]N-[(phenylmethyl)amine]. This amine (1.88g, 4.65mmol) was then reacted with tert-butylisocyanate (460.0mg, 4.6mmol) to afford 2.24g (96%) of [2(R), 3(S)]-N-[[3-(phenylmethylcarbamoyl)amino]-2-hydroxy-4-phenyl]-1-[(phenylmethyl)amino]-1-(1,1-dimethylethyl)amino]carbonyl] butane.
- b) The CBZ protected compound (2.22g, 4.4mmol) was then deprotected by hydrogenation over 10% palladium-on-carbon and the resulting free amine coupled with N-



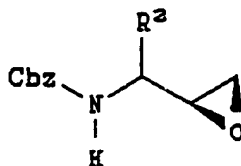
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CBZ-L-asparagine (1.17g, 4.4mmol) in the presence of N-hydroxybenzotriazole (1.19g, 8.8mmol) and EDC (843mg, 4.4mmol) to yield 2.11g (78%) of [1S-[1R\*(R\*), 2S\*]]-N<sup>1</sup>[3-[[[(1,1-dimethylethyl)amino]carbonyl](phenylmethyl)amino]-2-hydroxy-1-(phenylmethyl)propyl]-2-[(phenylmethylcarbamoyl)amino]-butanediamide; mp 156-158°C and MH<sup>+</sup> 618. This compound (1.0g, 1.62mmol) was then deprotected by hydrogenation over 10% palladium-on-carbon and the resulting free amine coupled with 2-quinolinecarboxylic acid N-hydroxysuccinimide ester (437mg, 1.62mmol), in the presence of N-methylmorpholine, to afford 640mg (62%) of pure [1S-[1R\*(R\*), 2S\*]]-N<sup>1</sup>[3-[[[(1,1-dimethylethyl)amino]carbonyl](phenylmethyl)amino]-2-hydroxy-1-(phenylmethyl)propyl]-2-[(2-quinolinylcarbonyl)amino]-butanediamide; mp 110.5-112.5°C and MH<sup>+</sup> 639.

EXAMPLE 9

Additional exemplary compounds of the present invention are listed in Table 1. These compounds were prepared according to the following general procedures. General Procedure for the Synthesis of 1,3-Diamino 4-phenyl Butan-2-ol Derivatives.

A mixture of the amine R<sup>3</sup>NH<sub>2</sub> (20 equiv.) in dry isopropyl alcohol (20mL/mmol of epoxide to be converted) was heated to reflux and then treated with an N-Cbz amino epoxide of the formula:



from a solids addition funnel over a 10-15 minute period. After the addition is complete the solution was maintained at reflux for an additional 15 minutes and the progress of the reaction monitored by TLC. The reaction mixture was then concentrated in vacuo to give an oil that was treated with n-hexane with rapid stirring whereupon the ring opened material precipitated from solution. Precipitation was generally complete within 1 hr and the product was then isolated by filtration on a Büchner funnel and then air dried. The product was further dried in vacuo. This method affords amino alcohols of sufficient purity for most purposes.

General procedure for the Reaction of Amino Alcohols with Isocyanates: Preparation of Ureas

A solution from the amino alcohol in tetrahydrofuran (THF) was treated at room temperature with the appropriate isocyanate of formula  $R'NCO$  via syringe under nitrogen. After the reaction has stirred for ~5m the progress of the reaction was monitored by TLC. The solvent was removed in vacuo and the product obtained was of sufficient purity for most purposes. The product may be further purified by dissolution in ethyl acetate and washing with 5% aqueous citric acid, water, and brine. The solvent is dried over anhydrous magnesium sulfate, filtered and concentrated in vacuo to give the pure urea.

General Procedure for the Removal of the Protecting Groups by Hydrogenolysis with Palladium on Carbon

A. Alcohol Solvent

The Cbz-protected peptide derivative was dissolved in methanol (ca. 20mL/mmol) and 10% palladium on carbon catalyst is added under a nitrogen atmosphere. The reaction vessel is sealed and flushed 5 times with nitrogen and then 5 times with hydrogen. The pressure is maintained at 50 psig for 1-16 hours and then the hydrogen replaced with nitrogen and the solution filtered through a pad of celite to remove the catalyst.

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The solvent is removed in vacuo to give the free amino derivative of suitable purity to be taken directly on to the next step.

**B. Acetic Acid Solvent**

5           The Cbz-protected peptide derivative was dissolved in glacial acetic acid (20mL/mmol) and 10% palladium on carbon catalyst is added under a nitrogen atmosphere. The reaction vessel is flushed 5 times with nitrogen and 5 times with hydrogen and then maintained  
10 at 40 psig for about 2h. The hydrogen was then replaced with nitrogen and the reaction mixture filtered through a pad of celite to remove the catalyst. The filtrate was concentrated and the resulting product taken up in anhydrous ether and evaporated to dryness 3 times. The  
15 final product, the acetate salt, was dried in vacuo and is of suitable purity for subsequent conversion.

**General Procedure for Removal of Boc-protecting Group with 4N Hydrochloric Acid in Dioxane**

          The Boc-protected amino acid or peptide is  
20 treated with a solution of 4N HCl in dioxane with stirring at room temperature. Generally the deprotection reaction is complete within 15 minutes, the progress of the reaction is monitored by thin layer chromatography (TLC). Upon completion, the excess  
25 dioxane and HCl are removed by evaporation in vacuo. The last traces of dioxane and HCl are best removed by evaporation again from anhydrous ether or acetone. The hydrochloride salt thus obtained is thoroughly dried in vacuo and is suitable for further reaction.

30 **EDC/HOBt Coupling of Cbz-Asparagine (General Procedure)**

          N-CBZ-(L-asparagine (1.10eq) and N-hydroxybenzotriazole (HOBt) (1.5eq) are dissolved in dry dimethylformamide (DMF) (2-5mL/nmol) and cooled in an ice bath. 1-(3-dimethylaminopropyl)-3-ethylcarbodiimide  
35 hydrochloride (EDC) (1.10eq) is added to the stirring solution and maintained at 0°C for 10 minutes. A solution of the amino component (free amine), 1.0eq in DMF (1-2mL/mmol), is added. [In the case of the amine

hydrochloride or acetate salt, an equivalent of N-methylemorpholine is also added.] The reaction mixture is stirred at 0°C for 1 hour and then at room temperature for ~5-6 hours. The reaction mixture is  
5 then poured into a rapidly stirring solution of 60% saturated aqueous sodium bicarbonate (ca-50mL/mmol). An immediate white precipitate forms which is collected on a Büchner funnel and the solid washed thoroughly with saturated aqueous sodium bicarbonate, water, 5% aqueous  
10 citric acid solution and water. The product is thoroughly dried in vacuo and redissolved in DMF, filtered and reprecipitated by the addition to water. The precipitated product is isolated by filtration, washed again with water and dried in vacuo.

15 General Procedure for Acylation with 2-Quinoline Carboxylic Acid N-Hydroxysuccinimide Ester

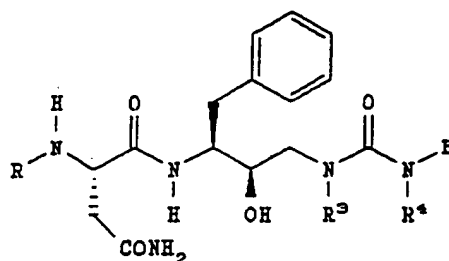
A solution of the free amine (or amine acetate salt) and 1.0 equivalent of N-hydroxysuccinimide 2-quinoline carboxylate in anhydrous dichloromethane was  
20 treated with 1.5 equivalents of N-methylemorpholine (NMM) at room temperature. The progress of the reaction was monitored by TLC and when the reaction was complete the reaction mixture was diluted with additional dichloromethane and the solution washed with saturated  
25 aqueous sodium bicarbonate, 5% aqueous citric acid, water and brine. The solution was dried over anhydrous magnesium sulfate, filtered and concentrated in vacuo. The product thus obtained was recrystallized from a mixture of acetone and hexane.

TABLE 1

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10

15



Entry No.	R	R <sup>3</sup>	R <sup>4</sup>
1	Cbz <sup>a</sup>	CH <sub>3</sub>	n-Butyl
2	Cbz	i-Butyl	CH <sub>3</sub>
3	Cbz	i-Butyl	n-Butyl
4	Q <sup>b</sup>	i-Butyl	n-Butyl
25 5	Cbz	i-Propyl	n-Butyl
6	Q	i-Propyl	n-Butyl
7	Cbz	C <sub>6</sub> H <sub>5</sub>	n-Butyl
8	Cbz	-CH <sub>2</sub> -	n-Butyl
9	Cbz	-CH <sub>2</sub> -	n-Butyl
30 10	Q	-CH <sub>2</sub> -	n-Butyl
11	Cbz	-	n-Butyl
12	Cbz	i-Butyl	n-Propyl
13	Cbz	i-Butyl	-CH <sub>2</sub> CH(CH <sub>3</sub> ) <sub>2</sub>
14	Cbz	(R) - CH(CH <sub>3</sub> ) -	n-Butyl
35 15	Cbz	-CH <sub>2</sub> -	i-Propyl
16	Cbz	-CH <sub>2</sub> -	-CH <sub>2</sub> CH <sub>2</sub> CH(CH <sub>3</sub> ) <sub>2</sub>
17	Cbz	i-Butyl	-CH <sub>2</sub> CH <sub>3</sub>
18	Cbz	i-Butyl	-CH(CH <sub>3</sub> ) <sub>2</sub>

TABLE 1 (Cont'd)










Entry No.	R	R <sup>3</sup>	R <sup>4</sup>
5 19	Cbz	i-Butyl	
20	Q	i-Butyl	
21	Cbz	-CH <sub>2</sub> 	-(CH <sub>2</sub> ) <sub>2</sub> CH(CH <sub>3</sub> ) <sub>2</sub>
22	Cbz	(CH <sub>2</sub> ) <sub>2</sub> CH(CH <sub>3</sub> ) <sub>2</sub>	-CH(CH <sub>3</sub> ) <sub>2</sub>
23	Q	i-Butyl	-CH(CH <sub>3</sub> ) <sub>2</sub>
10 24	Cbz	i-Butyl	-C(CH <sub>3</sub> ) <sub>3</sub>
25	Q	i-Butyl	-C(CH <sub>3</sub> ) <sub>3</sub>
26	Cbz	-CH <sub>2</sub> 	-C(CH <sub>3</sub> ) <sub>3</sub>
27	Q	-CH <sub>2</sub> 	-C(CH <sub>3</sub> ) <sub>3</sub>
28	Cbz	-(CH <sub>2</sub> ) <sub>2</sub> CH(CH <sub>3</sub> ) <sub>2</sub>	-C(CH <sub>3</sub> ) <sub>3</sub>
15 29	Q	-(CH <sub>2</sub> ) <sub>2</sub> CH(CH <sub>3</sub> ) <sub>2</sub>	-C(CH <sub>3</sub> ) <sub>3</sub>
30	Cbz	-CH <sub>2</sub> C <sub>6</sub> H <sub>5</sub>	-C(CH <sub>3</sub> ) <sub>3</sub>
31	Q	-CH <sub>2</sub> C <sub>6</sub> H <sub>5</sub>	-C(CH <sub>3</sub> ) <sub>3</sub>
32	Cbz	-(CH <sub>2</sub> ) <sub>2</sub> C <sub>6</sub> H <sub>5</sub>	-C(CH <sub>3</sub> ) <sub>3</sub>
33	Cbz	-(CH <sub>2</sub> ) <sub>2</sub> C <sub>6</sub> H <sub>5</sub>	-C(CH <sub>3</sub> ) <sub>3</sub>
20 34	Cbz	n-Butyl	-C(CH <sub>3</sub> ) <sub>3</sub>
35	Cbz	n-Pentyl	-C(CH <sub>3</sub> ) <sub>3</sub>
36	Cbz	n-Hexyl	-C(CH <sub>3</sub> ) <sub>3</sub>
37	Cbz	-CH <sub>2</sub> 	-C(CH <sub>3</sub> ) <sub>3</sub>
38	Cbz	-CH <sub>2</sub> C(CH <sub>3</sub> ) <sub>3</sub>	-C(CH <sub>3</sub> ) <sub>3</sub>
25 39	Q	-CH <sub>2</sub> C(CH <sub>3</sub> ) <sub>3</sub>	-C(CH <sub>3</sub> ) <sub>3</sub>
40	Cbz	-CH <sub>2</sub> CH <sub>2</sub> - 	-C(CH <sub>3</sub> ) <sub>3</sub>
41	Cbz	-CH <sub>2</sub> C <sub>6</sub> H <sub>5</sub> OCH <sub>3</sub> (para)	-C(CH <sub>3</sub> ) <sub>3</sub>
42	Cbz	-CH <sub>2</sub> 	-C(CH <sub>3</sub> ) <sub>3</sub>
43	Cbz	-CH <sub>2</sub> - 	-C(CH <sub>3</sub> ) <sub>3</sub>
30 44	Cbz	-(CH <sub>2</sub> ) <sub>2</sub> C(CH <sub>3</sub> ) <sub>3</sub>	-C(CH <sub>3</sub> ) <sub>3</sub>
45	Q	-(CH <sub>2</sub> ) <sub>2</sub> C(CH <sub>3</sub> ) <sub>3</sub>	-C(CH <sub>3</sub> ) <sub>3</sub>
46	Cbz	-(CH <sub>2</sub> ) <sub>4</sub> OH	-C(CH <sub>3</sub> ) <sub>3</sub>

TABLE 1 (Cont'd)



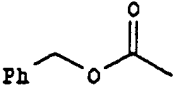
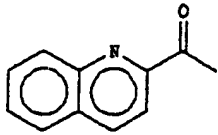
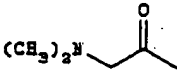
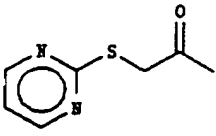
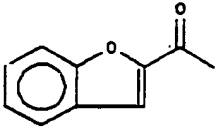
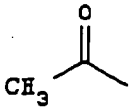
Entry No.	R	R <sup>3</sup>	R <sup>4</sup>
5 47.	Q	$-(\text{CH}_2)_4\text{OH}$	$-\text{C}(\text{CH}_3)_3$
48.	Q	$-\text{CH}_2-$ 	$-\text{C}(\text{CH}_3)_3$
49.	Q	$-\text{CH}_2-$ 	$-\text{C}(\text{CH}_3)_3$
50.		$-\text{CH}_2\text{CH}(\text{CH}_3)_2$	$-\text{C}(\text{CH}_3)_3$
51.		"	"
10 52.		"	"
53.		"	"
54.		"	"
55.		"	"

TABLE 1 (Cont'd)

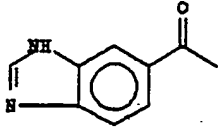
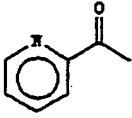
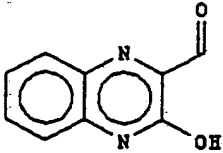
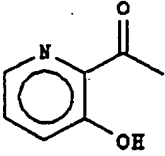
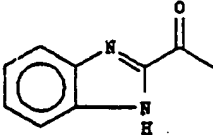
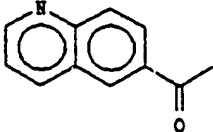
Entry No.	R	R <sup>3</sup>	R <sup>4</sup>
5	56.		" "
	57.		" "
	58.		" "
	59.		" "
	60.		" "
10	61.		" "



TABLE 1 (Cont'd)

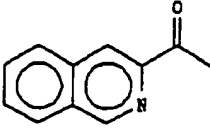
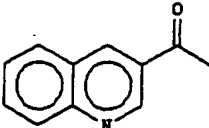
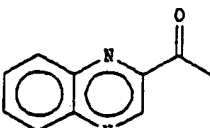
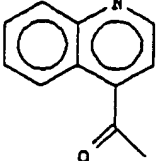
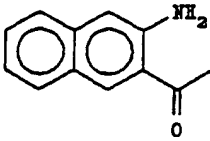
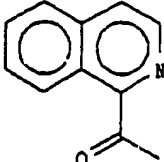
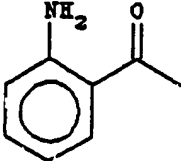
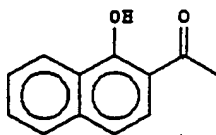
Entry No.	R	R <sup>3</sup>	R <sup>4</sup>
5 62.		"	"
63.		"	"
64.		"	"
65.		"	"
66.		"	"
10 67.		"	"
68.		"	"

TABLE 1 (Cont'd)

Entry No.	R	R <sup>3</sup>	R <sup>4</sup>
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5

69.



" "

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<sup>a</sup> benzyloxycarbonyl  
<sup>b</sup> 2-quinolinylcarbonyl

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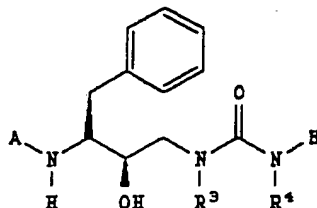
EXAMPLE 10

Following the generalized procedures set forth in Example 9, the compounds set forth in Table 2 were prepared.

TABLE 2

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Entry	A	R <sup>3</sup>	R <sup>4</sup>
1.	Cbz-Val	<u>i</u> -amyl	tBu
2.	Cbz-Leu	<u>i</u> -amyl	<u>t</u> -Bu
3.	Cbz-Ile	<u>i</u> -amyl	<u>t</u> -Bu
4.	Ac-D- <u>homo</u> -Phe	<u>i</u> -Bu	<u>n</u> -Bu
5.	Qui-Orn( $\gamma$ -Cbz)	-CH <sub>2</sub> -	<u>t</u> -Bu
6.	Cbz-Asn	-CH <sub>2</sub> CH=CH <sub>2</sub>	<u>t</u> -Bu
7.	Acetyl-t-BuGly	<u>i</u> -amyl	<u>t</u> -Bu
8.	Acetyl-Phe	<u>i</u> -amyl	<u>t</u> -Bu
9.	Acetyl-Ile	<u>i</u> -amyl	<u>t</u> -Bu
10.	Acetyl-Leu	<u>i</u> -amyl	<u>t</u> -Bu
11.	Acetyl-His	<u>i</u> -amyl	<u>t</u> -Bu
12.	Acetyl-Thr	<u>i</u> -amyl	<u>t</u> -Bu
13.	Acetyl-NHCH(C(CH <sub>3</sub> ) <sub>2</sub> (SCH <sub>3</sub> ))C(O)-	<u>i</u> -amyl	<u>t</u> -Bu
14.	Cbz-Asn	<u>i</u> -amyl	<u>t</u> -Bu
15.	Cbz-Ala	<u>i</u> -amyl	<u>t</u> -Bu
16.	Cbz-Ala	<u>i</u> -amyl	<u>t</u> -Bu
17.	Cbz-beta-cyanoAla	<u>i</u> -amyl	<u>t</u> -Bu
18.	Cbz-t-BuGly	<u>i</u> -amyl	<u>t</u> -Bu
19.	Q-t-BuGly	<u>i</u> -amyl	<u>t</u> -Bu
20.	Q-SCH <sub>3</sub> Cys	<u>i</u> -amyl	<u>t</u> -Bu
21.	Cbz-SCH <sub>3</sub> Cys	<u>i</u> -amyl	<u>t</u> -Bu

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TABLE 2 (Cont'd)

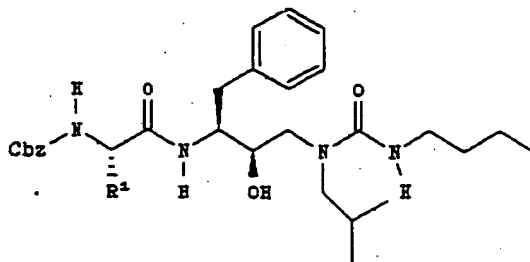
Entry	A	R <sup>3</sup>	R <sup>4</sup>
5	22. Q-Asp	<i>i</i> -amyl	<i>t</i> -Bu
	23. Cbz-(NHCH(C(CH <sub>3</sub> ) <sub>2</sub> (SCH <sub>3</sub> ))C(O)-	<i>i</i> -amyl	<i>t</i> -Bu
	24. Cbz-EtGly	<i>i</i> -amyl	<i>t</i> -Bu
	25. Cbz-PrGly	<i>i</i> -amyl	<i>t</i> -Bu
	26. Cbz-Thr	<i>i</i> -amyl	<i>t</i> -Bu
10	27. Q-Phe	<i>i</i> -amyl	<i>t</i> -Bu
	28. Cbz-Phe	<i>i</i> -amyl	<i>t</i> -Bu

## EXAMPLE 11

Following the generalized procedure of Example 9, the compounds listed in Table 3 were prepared.

TABLE 3

Entry	R <sup>1</sup>
1	CH <sub>2</sub> SO <sub>2</sub> CH <sub>3</sub>
2	(R)-CH(OH)CH <sub>3</sub>
3	CH(CH <sub>3</sub> ) <sub>2</sub>
4	(R,S)CH <sub>2</sub> SOCH <sub>3</sub>
5	CH <sub>2</sub> SO <sub>2</sub> NH <sub>2</sub>
6	CH <sub>2</sub> SCH <sub>3</sub>
7	CH <sub>2</sub> CH(CH <sub>3</sub> ) <sub>2</sub>
8	CH <sub>2</sub> CH <sub>2</sub> C(O)NH <sub>2</sub>
9	(S)-CH(OH)CH <sub>3</sub>



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EXAMPLE 12

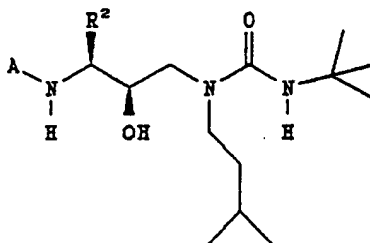
Following the generalized procedures of Example 9, the compounds set forth in Table 4 were prepared.

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TABLE 4

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Entry	R <sup>2</sup>	A
1.	n-Bu	Cbz-Asn
2.	cyclohexylmethyl	Cbz-Asn
3.	n-Bu	Boc
4.	n-Bu	Cbz
5.	C <sub>6</sub> H <sub>5</sub> CH <sub>2</sub>	Boc
6.	C <sub>6</sub> H <sub>5</sub> CH <sub>2</sub>	Cbz
7.	C <sub>6</sub> H <sub>5</sub> CH <sub>2</sub>	benzoyl
8.	cyclohexylmethyl	Cbz
9.	n-Bu	Q-Asn
10.	cyclohexylmethyl	Q-Asn
11.	C <sub>6</sub> H <sub>5</sub> CH <sub>2</sub>	Cbz-Ile
12.	C <sub>6</sub> H <sub>5</sub> CH <sub>2</sub>	Q-Ile
13.	C <sub>6</sub> H <sub>5</sub> CH <sub>2</sub>	Cbz-t-BuGly
14.	C <sub>6</sub> H <sub>5</sub> CH <sub>2</sub>	Q-t-BuGly
15.	C <sub>6</sub> H <sub>5</sub> CH <sub>2</sub>	Cbz-Val
16.	C <sub>6</sub> H <sub>5</sub> CH <sub>2</sub>	Q-Val
17.	2-naphthylmethyl	Cbz-Asn
18.	2-naphthylmethyl	Q-Asn
19.	2-naphthylmethyl	Cbz
20.	n-Bu	Cbz-Val
21.	n-Bu	Q-Val
22.	n-Bu	Q-Ile

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TABLE 4 (Cont'd)

Entry	R <sup>2</sup>	A
23.	n-Bu	Cbz-t-BuGly
24.	n-Bu	Q-t-BuGly
25.	p-F(C <sub>6</sub> H <sub>4</sub> )CH <sub>2</sub>	Q-Asn
26.	p-F(C <sub>6</sub> H <sub>4</sub> )CH <sub>2</sub>	Cbz
27.	p-F(C <sub>6</sub> H <sub>4</sub> )CH <sub>2</sub>	Cbz-Asn

10

EXAMPLE 13

The compounds listed in Table 5 were prepared according to the generalized procedures of Example 9.

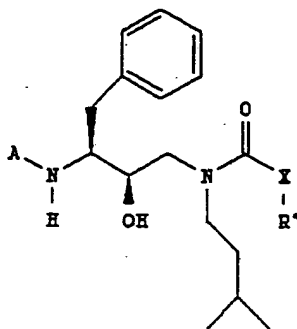
TABLE 5

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Entry	XR <sup>4</sup>	A
1.	-NH <sup>t</sup> Bu	Cbz-Asn
2.	-NEt <sub>2</sub>	Cbz
3.	-NHC(CH <sub>3</sub> ) <sub>2</sub> CH <sub>2</sub> CH <sub>3</sub>	Cbz

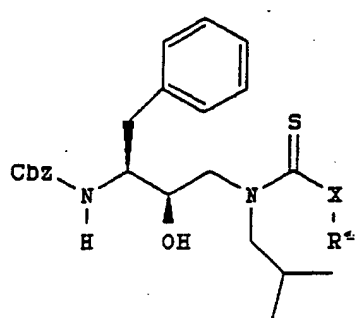
40

EXAMPLE 14

The compounds of Table 6 were prepared according to the generalized procedures set forth in Example 9 except that instead of an isocyanate, an isothiocyanate equivalent was utilized.

-53-

Tabl 6

5							
10							
15							
20	<table border="1"> <thead> <tr> <th>Entry</th><th>XHR<sup>4</sup></th></tr> </thead> <tbody> <tr> <td>1.</td><td>NHEt</td></tr> <tr> <td>2.</td><td>NH<sup>t</sup>Bu</td></tr> </tbody> </table>	Entry	XHR <sup>4</sup>	1.	NHEt	2.	NH <sup>t</sup> Bu
Entry	XHR <sup>4</sup>						
1.	NHEt						
2.	NH <sup>t</sup> Bu						

25 The Cbz group of the compounds shown in Examples 13 and 14 can be removed as described in Example 9 and the resulting compound can be coupled to a desired  $\alpha$ - or  $\beta$ -amino acid or the like to produce compounds of the present invention.

30

#### Example 15

The compounds shown in Table 7 were prepared according to the following general procedure.

This general procedure represents a Curtius

35 Rearrangement and reaction with the amino alcohol derivative as prepared following the general procedure in Example 9.

To a solution of 1 mmol of carboxylic acid in 12 mL of toluene and 3 mmol of triethylamine at 90°C  
 40 under a nitrogen atmosphere, was added 1 mmol of diphenylphosphoryl azide. After 1 hour, a solution of 1 mmol of amino alcohol derivative in 3.5 mL of either N,N-dimethylformamide or toluene was added. After 1 hour, the solvent was removed under reduced pressure ,

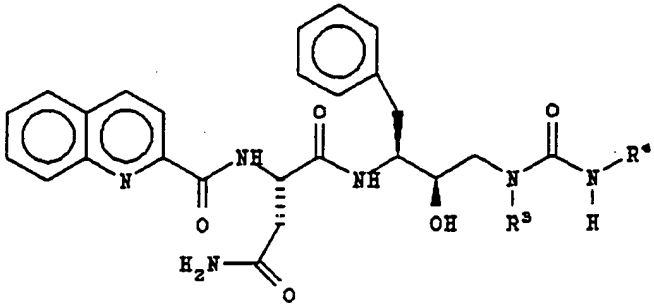




-54-

ethyl acetate and water added and the layers separated. The organic layer was washed with 5% citric acid, sodium bicarbonate, brine, dried, filtered and concentrated to afford the crude product. This was then recrystallized  
5 or chromatographed on silica gel to afford the purified final compound.



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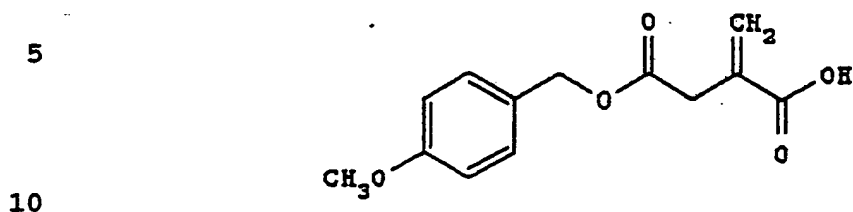
TABLE 7

5		
10	<u>R<sup>3</sup></u>	<u>R<sup>4</sup></u>
15	$-\text{CH}_2\text{CH}(\text{CH}_3)_2$	$-\text{C}(\text{CH}_3)_2$
20	$-\text{CH}_2\text{CH}_2\text{CH}(\text{CH}_3)_2$	
	$-\text{CH}_2\text{CH}_2\text{CH}(\text{CH}_3)_2$	
	$-\text{CH}_2\text{CH}_2\text{CH}(\text{CH}_3)_2$	
	$-\text{CH}_2\text{CH}_2\text{CH}(\text{CH}_3)_2$	

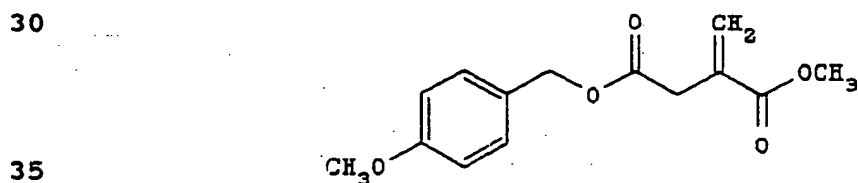
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Example 16A. Preparation of 4(4-methoxybenzyl)itaconate

A 5 L three-necked round bottomed flask equipped with constant pressure addition funnel, reflux condenser, nitrogen inlet, and mechanical stirrer was charged with itaconic anhydride (660.8g, 5.88 mol) and toluene (2300 mL). The solution was warmed to reflux and treated with 4-methoxybenzyl alcohol (812.4g, 5.88 mol) dropwise over a 2.6h period. The solution was maintained at reflux for an additional 1.5h and then the contents were poured into three 2 L erlenmeyer flasks to crystallize. The solution was allowed to cool to room temperature whereupon the desired mono-ester crystallized. The product was isolated by filtration on a Buchner funnel and air dried to give 850.2g, 58% of material with mp 83-85°C, a second crop, 17% was isolated after cooling of the filtrate in an ice bath. <sup>1</sup>H NMR (CDCl<sub>3</sub>) 300 MHz 7.32(d, J=8.7 Hz, 2H), 6.91(d, J=8.7 Hz, 2H), 6.49(s, 1H), 5.85(s, 1H), 5.12(s, 2H), 3.83(s, 3H), 3.40(s, 2H).

B. Preparation of Methyl 4(4-methoxybenzyl) itaconate

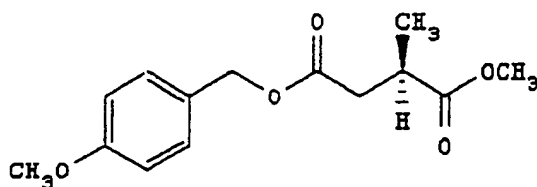
A 5 L three-necked round bottomed flask equipped with reflux condenser, nitrogen inlet, constant pressure addition funnel and mechanical stirrer was charged with 4(4-methoxybenzyl) itaconate (453.4g, 1.81 mol) and treated with 1,5-diazabicyclo[4.3.0]non-5-ene (275.6g, 1.81 mol), (DBU), dropwise so that the temperature did

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not rise above 15°C. To this stirring mixture was added a solution of methyl iodide (256.9g, 1.81 mol) in 250 mL of toluene from the dropping funnel over a 45m period. The solution was allowed to warm to room temperature and stirred for an additional 3.25h.

The precipitated DBU hydroiodide was removed by filtration, washed with toluene and the filtrate poured into a separatory funnel. The solution was washed with sat. aq. NaHCO<sub>3</sub> (2 X 500 mL), 0.2N HCl (1 X 500 mL), and brine (2 X 500 mL), dried over anhyd. MgSO<sub>4</sub>, filtered, and the solvent removed in vacuo. This gave a clear colorless oil, 450.2g, 94% whose NMR was consistent with the assigned structure. <sup>1</sup>H NMR (CDCl<sub>3</sub>) 300 MHz 7.30(d, J=8.7 Hz, 2H), 6.90(d, J=8.7 Hz, 2H), 6.34(s, 1H), 5.71(s, 1H), 5.09(s, 2H), 3.82(s, 3H), 3.73(s, 3H), 3.38(s, 2H). <sup>13</sup>C NMR (CDCl<sub>3</sub>) 170.46, 166.47, 159.51, 133.55, 129.97, 128.45, 127.72, 113.77, 66.36, 55.12, 51.94, 37.64.

C. Preparation of Methyl 4(4-methoxybenzyl) 2(R)-methylsuccinate



A 500 mL Fisher-Porter bottle was charged with methyl 4(4-methoxybenzyl) itaconate (71.1g, 0.269 mol), rhodium (R,R) DiPAMP catalyst (204mg, 0.269 mmol, 0.1 mol%) and degassed methanol (215 mL). The bottle was flushed 5 times with nitrogen and 5 times with hydrogen to a final pressure of 40 psig. The hydrogenation commenced immediately and after ca. 1h the uptake began to taper off, after 3h the hydrogen uptake ceased and the bottle was flushed with nitrogen, opened and the contents concentrated on a rotary evaporator to give a brown oil that was taken up in boiling iso-octane (ca. 200 mL,

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this was repeated twice), filter d through a pad of celite and the filtrate concentrated in vacuo to give 66.6g, 93% of a clear colorless oil, <sup>1</sup>H NMR (CDCl<sub>3</sub>, 300 MHz) 7.30(d, J=8.7 Hz, 2H), 6.91(d, J=8.7 Hz, 2H), 5.08(s, 2H), 3.82(s, 3H), 3.67(s, 3H), 2.95(ddq, J=5.7, 7.5, 8.7 Hz, 1H), 2.79(dd, J=8.1, 16.5 Hz, 1H), 2.45(dd, J=5.7, 16.5 Hz, 1H), 1.23(d, J=7.5 Hz, 3H).

#### D. Preparation of Methyl 2(R)-methylsuccinate

10 A 3 L three-necked round-bottomed flask equipped with a nitrogen inlet, mechanical stirrer, reflux condenser and constant pressure addition funnel was charged with methyl 4(4-methoxybenzyl) 2(R)-methylsuccinate (432.6g, 1.65 mol) and toluene (1200 mL). The stirrer was started and the solution treated with trifluoroacetic acid (600 mL) from the dropping funnel over 0.25h. The solution turned a deep purple color and the internal temperature rose to 45°C. After stirring for 2.25h the temperature was 27°C and the solution had acquired a pink color. The solution was concentrated on a rotary evaporator. The residue was diluted with water (2200 mL) and sat. aq. NaHCO<sub>3</sub> (1000 mL). Additional NaHCO<sub>3</sub> was added until the acid had been neutralized. The aqueous phase was extracted with ethyl acetate (2 X 1000 mL) to remove the by-products and the aqueous layer was acidified to pH=1.8 with conc. HCl. This solution was extracted with ethyl acetate (4 X 1000 mL), washed with brine, dried over anhyd. MgSO<sub>4</sub>, filtered and concentrated on a rotary evaporator to give a colorless liquid 251g, >100% that was vacuum distilled through a short path apparatus cut 1: bath temperature 120°C @ >1mm, bp 25-29°C; cut 2: bath temperature 140°C @ 0.5mm, bp 95-108°C, 151g, [α]<sub>D</sub> @ 25°C=+1.38°C(c=15.475, MeOH), [α]<sub>D</sub>=+8.48°C (neat); cut 3: bath temperature 140°C, bp 108°C, 36g, [α]<sub>D</sub> @ 25°C=+1.49°C(c=15.00, MeOH), [α]<sub>D</sub>=+8.98°C (neat). Cuts 2 and 3 were combined to give 189g, 78% of product, <sup>1</sup>H NMR (CDCl<sub>3</sub>, 300 MHz) 11.6(brs, 1H), 3.72(s, 3H), 2.92(ddq, J=5.7, 6.9, 8.0 Hz, 1H),

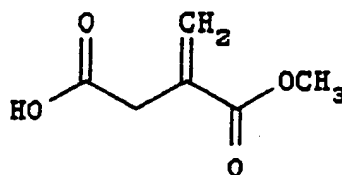
-59-

2.81(dd, J=8.0, 16.8 Hz, 1H), 2.47(dd, J=5.7, 16.8 Hz, 1H), 1.26(d, J=6.9 Hz, 3H).

E. Preparation of Methyl Itaconate

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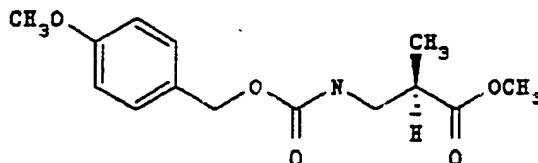


A 50 mL round bottomed flask equipped with reflux condenser, nitrogen inlet and magnetic stir bar was charged with methyl 4(4-methoxybenzyl) itaconate (4.00g, 16 mmol). The solution was kept at room temperature for 18 hours and then the volatiles were removed in vacuo. The residue was taken up in ethyl acetate and extracted three times with saturated aqueous sodium bicarbonate solution. The combined aqueous extract was acidified to pH=1 with aqueous potassium bisulfate and then extracted three times with ethyl acetate. The combined ethyl acetate solution was washed with saturated aqueous sodium chloride, dried over anhydrous magnesium sulfate, filtered, and concentrated in vacuo. The residue was then vacuum distilled to give 1.23g, 75% of pure product, bp 85-87 @ 0.1 mm. <sup>1</sup>H NMR (CDCl<sub>3</sub>) 300 MHz 6.34(s, 1H), 5.73(s, 2H), 3.76(s, 3H), 3.38(s, 2H). <sup>13</sup>C NMR (CDCl<sub>3</sub>) 177.03, 166.65, 129.220, 132.99, 52.27, 37.46.

F. Curtius Rearrangement of Methyl 2(R)-methylsuccinate:  
Preparation of Methyl N-Moz-α-methyl β-alanine.

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A 5L four necked round bottomed flask equipped with a nitrogen inlet, reflux condenser, mechanical stirrer, constant pressure addition funnel, and thermometer

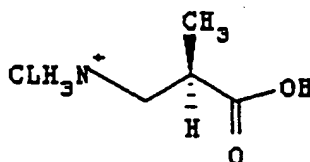
-60-

adapter was charged with methyl 2(R)-methylsuccinate (184.1g, 1.26 mol), triethylamine (165.6g, 218 mL, 1.64 mol, 1.3 equivalents), and toluene (1063 mL). The solution was warmed to 85°C and then treated dropwise with a solution of diphenylphosphoryl azide (346.8g, 1.26 mol) over a period of 1.2h. The solution was maintained at that temperature for an additional 1.0h and then the mixture was treated with 4-methoxybenzyl alcohol (174.1g, 1.26 mol) over a 0.33h period from the dropping funnel. The solution was stirred at 88°C for an additional 2.25h and then cooled to room temperature. The contents of the flask were poured into a separatory funnel and washed with sat. aq. NaHCO<sub>3</sub> (2 X 500 mL), 0.2N HCl (2 X 500 mL), brine (1 X 500 mL), dried over anhyd. MgSO<sub>4</sub>, filtered, and concentrated *in vacuo* to give 302.3g, 85% of the desired product as a slightly brown oil. <sup>1</sup>H NMR (CDCl<sub>3</sub>) 300 MHz 7.32(d, J=8.4 Hz, 2H), 6.91(d, J=8.4 Hz, 2H), 5.2(brm, 1H), 5.05(s, 2H), 3.83(s, 3H), 3.70(s, 3H), 3.35(m, 2H), 2.70(m, 2H), 1.20(d, J=7.2 Hz, 3H).

G. Hydrolysis of Methyl N-Moz-α-methyl β-alanine:

Preparation of α-methyl β-alanine Hydrochloride

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A 5 L three-necked round bottomed flask equipped with a reflux condenser, nitrogen inlet and mechanical stirrer was charged with methyl N-Moz-α-methyl β-alanine (218.6g, 0.78 mol), glacial acetic acid (975 mL) and 12N hydrochloric acid (1960 mL). The solution was then heated to reflux for 3h. After the solution had cooled to room temperature (ca. 1h) the aqueous phase was decanted from organic residue (polymer) and the aqueous phase concentrated on a rotary

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vap rator. Upon addition of acetone to the concentrated residue a slightly yellow solid formed that was slurried with acetone and the white solid was isolated by filtration on a Buchner funnel. The last traces of acetone were removed by evacuation to give 97.7g, 90% of pure product, mp 128.5-130.5°C [ $\alpha$ ]<sub>D</sub> @ 25°C=9.0°C (c=2.535, Methanol). <sup>1</sup>H NMR (D<sub>2</sub>O) 300 MHz 3.29(dd, J=8.6, 13.0 Hz, 1H), 3.16(dd, J=5.0, 13.0 Hz, 1H), 2.94(ddq, J=7.2, 5.0, 8.6 Hz, 1H), 1.30(d, J=7.2 Hz, 3H); <sup>13</sup>C NMR (D<sub>2</sub>O) 180.84, 44.56, 40.27, 17.49.

H. Preparation of N-Boc  $\alpha$ -Methyl  $\beta$ -Alanine



20 A solution of  $\alpha$ -methyl  $\beta$ -alanine hydrochloride (97.7g, 0.70 mol) in water (1050 mL) and dioxane (1050 mL) the pH was adjusted to 8.9 with 2.9N NaOH solution. This stirring solution was then treated with di-tert-butyl pyrocarbonate (183.3g, 0.84 mol, 1.2 equivalents) all at once. The pH of the solution was maintained between 8.7 and 9.0 by the periodic addition of 2.5N NaOH solution. After 2.5h the pH had stabilized and the reaction was judged to be complete. The solution was concentrated on a rotary evaporator (the temperature was maintained at <40°C). The excess di-tert-butyl pyrocarbonate was removed by extraction with dichloromethane and then the aqueous solution was acidified with cold 1N HCl and immediately extracted with ethyl acetate (4 X 1000 mL). The combined ethyl acetate extract was washed with brine, dried over anhyd. MgSO<sub>4</sub>, filtered and concentrated on a rotary evaporator to give a thick oil 127.3g, 90% crude yield that was stirred with n-hexane whereupon crystals of pure product formed, 95.65g, 67%, mp 76-78°C, [ $\alpha$ ]<sub>D</sub> @ 25°C=-11.8°C (c=2.4, EtOH). A second crop was obtained by concentration of the filtrate and dilution with hexane,

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15.4g, for a combined yield of 111.05g, 78%. <sup>1</sup>H NMR (acetone D<sub>6</sub>) 300 MHz 11.7 (brs, 1H), 6.05 (brs 1H), 3.35 (m, 1H), 3.22 (m, 1H), 2.50 (m, 1H), 1.45(s, 9H), 1.19 (d, J=7.3 Hz, 3H); <sup>13</sup>C NMR (acetone D<sub>6</sub>) 177.01, 79.28, 44.44, 40.92, 29.08, 15.50. Elemental analysis calc'd. for C<sub>9</sub>H<sub>17</sub>NO<sub>4</sub>: C, 53.19, H, 8.42; N, 6.89. Found: C, 53.36; H, 8.46; N, 6.99.

I. Preparation of N-4-Methoxybenzyloxycarbonyl α-Methyl β-Alanine

10 A solution of N-4-methoxybenzyloxycarbonyl α-methyl β-alanine methyl ester (2.81g, 10.0 mmol) in 30 mL of 25% aqueous methanol was treated with lithium hydroxide (1.3 equivalents) at room temperature for a period of 2h. The solution was concentrated in vacuo and the residue taken up in a mixture of water and ether and the phases separated and the organic phase discarded. The aqueous phase was acidified with aqueous potassium hydrogen sulfate to pH=1.5 and then extracted three times with ether. The combined ethereal phase was washed with saturated aqueous sodium chloride solution, dried over anhydrous magnesium sulfate, filtered and concentrated in vacuo to give 2.60 g, 97% of N-4-Methoxybenzyloxycarbonyl α-methyl β-alanine (N-Moz-AMBA) which was purified by recrystallization from a mixture of ethyl acetate and hexane to give 2.44g, 91% of pure product, mp 96-97°C, MH<sup>+</sup>=268. <sup>1</sup>H NMR (D<sub>6</sub>-acetone/300 MHz) 1.16 (3H, d, J=7.2Hz), 2.70 (1H, m), 3.31 (2H, m), 3.31 (3H, s), 4.99 (2H, s), 6.92 (2H, 4, J=8.7 Hz), 7.13 (2H, d, J=8.7 Hz).

30 J. Preparation of Propanamide, 3-(4-methoxybenzyloxycarbonyl)-N-[3-[[[(1,1-dimethylethyl)amine]carbonyl](3-methylbutyl)amino]-2-hydroxy-1-(phenylmethyl)propyl]-2-methyl-[1S-[IR\*(S\*)], 2S\*]]-

35 N-Moz-AMBA (468mg, 1.75mmol) was dissolved in 5mL of DMF, HOBT (355mg, 2.6mmol) was added and the solution was cooled to 0°C. The solution was treated with (336mg, 1.75mmol) EDC for 15 minutes. To this was



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added (612mg, 1.75mmol) of [2R,3S 3-amino-1-isoamyl-1-(t-butylcarbonyl)amino 4-phenyl-2-butan 1 in 10mL of DMF and the reaction stirred for 16 hours at room temperature. The DMF was concentrated to 5mL and the product was precipitated by addition to 60% saturated aqueous NaHCO<sub>3</sub>. The solid was taken up in ethyl acetate and washed with KHSO<sub>4</sub>, NaHCO<sub>3</sub>, NaCl(saturated), dried over MgSO<sub>4</sub> and concentrated to yield 680mg of crude product which was crystallized from CH<sub>2</sub>Cl<sub>2</sub>, Et<sub>2</sub>O, hexane, to yield 300mg of pure product.

#### Example 17

The compounds of Table 8 were prepared according to the procedure listed below and that utilized in Example 16.

15 Propaneamide, 3-[(1,1-dimethylethyl)butoxycarbonyl]amino-N-[3-[(1,1-dimethylethyl)amino]carbonyl](3-methylbutyl)amino]-2-hydroxy-1-(phenylmethyl)propyl]-2-methyl-, [1S-[1R\*(S\*),2S\*]- (Table 8, Entry 11)

#### 20 Part A.

A solution of N-t-butyloxycarbonyl-2-(R)-methyl-3-aminopropionic acid (372 mg, 1.83 mmol) and N-hydroxybenzotriazole (371 mg, 2.75 mmol) in 5 mL of dimethylformamide was cooled to 0°C. To this was added EDC (351 mg, 1.83 mmol) and the solution was stirred for 15 minutes. To this chilled solution was added a solution of 3-[(1,1-dimethylethyl)amino]carbonyl(3-methylbutyl)amino]-2(R)-hydroxy-1(S)(phenylmethyl)propylamine in 5 mL of dimethylformamide and stirred for 15 hours. The dimethylformamide was removed and replaced with 50 mL of ethyl acetate, and the organic phase was extracted with 5% potassium hydrogen sulfate, saturated sodium bicarbonate and brine. The ethyl acetate layer was dried over magnesium sulfate, filtered and concentrated to yield 613 mg of product after recrystallization from ethyl acetate, hexanes. (63 % yield). N+Li 541

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Part B.

Preparation of Propaneamide, 3-amino-N-[3-  
[[[(1,1-dimethylethyl)amino] carbonyl]- (3-  
methylbutyl)amino]-2-hydroxy-1-(phenylmethyl)propyl]-2-  
5 methyl-, [1S-[1R\*(S\*), 2S\*]-  
hydrochloride

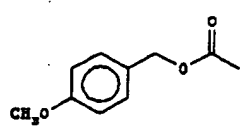
The product from part A. (577 mg, 1.08 mmol)  
was dissolved in 40 mL of 4N HCl in dioxane and the  
solution stirred for 2 hours, and concentrated to yield  
10 the hydrochloride salt in quantitative yield.

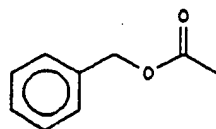
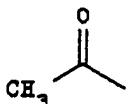
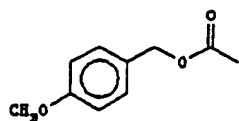
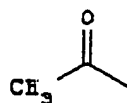
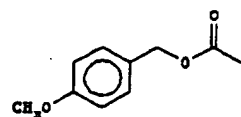
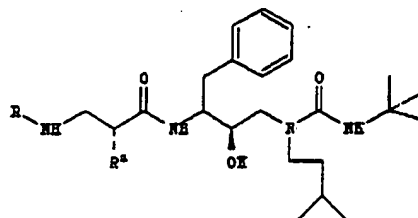
Part C.

Preparation of Propaneamide, 3-(2-  
methylpropanoylamino)-N-[3-[[[(1,1-dimethylethyl)-  
amino]carbonyl](3-methylbutyl)amino]-2-hydroxy-1-  
15 (phenylmethyl)propyl]-2-methyl-, [1S-[1R\*(S\*), 2S\*]-

The product from part B. (236 mg, 0.5 mmol)  
was dissolved in anhydrous tetrahydrofuran and to this  
was added N-methylmorpholine (160 mg, 1.5 mmol) upon  
which time a precipitate formed. To this suspension was  
20 added isobutyryl chloride ( 53.5 mg, 0.5 mmol) and the  
suspension stirred for 15 hours. The suspension was  
diluted with ethyl acetate and washed with 5% potassium  
hydrogen sulfate, saturated sodium bicarbonate and  
brine. the organic layer was dried over magnesium  
25 sulfate, filtered and concentrated to yield 195 mg of  
crude product which was chromatographed on silica gel  
with 5% methanol methylene chloride to yield 121.5 mg (  
50 % yield) of pure product. M+Li 511

TABLE 8

5		
10		
15	<u>R</u>	<u>R<sub>1</sub></u>
20	1.	
		-CH <sub>3</sub>



-66-

TABLE 8 (Cont'd)

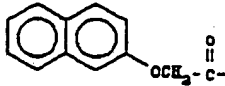
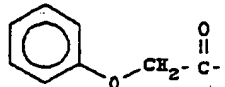
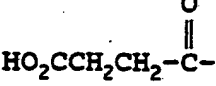
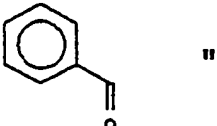

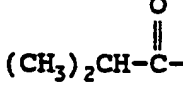
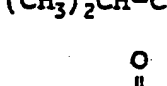
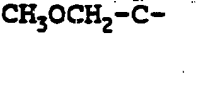
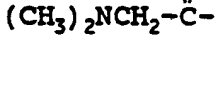
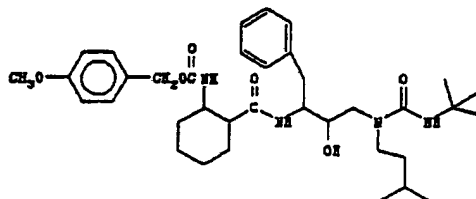
5	R	R <sub>1</sub>
6.		-CH <sub>3</sub>
10 7.		-CH <sub>3</sub>
8.		"
15 9.		"
20 10.		"
11.		"
25 12.		"
30 13.		"
35 14.		"
40		

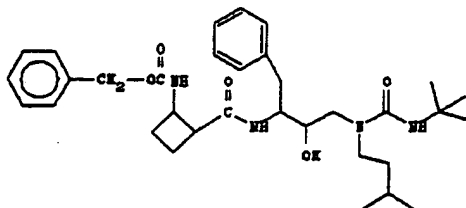
TABLE 8 (Cont'd)

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15.



16.



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Example 18

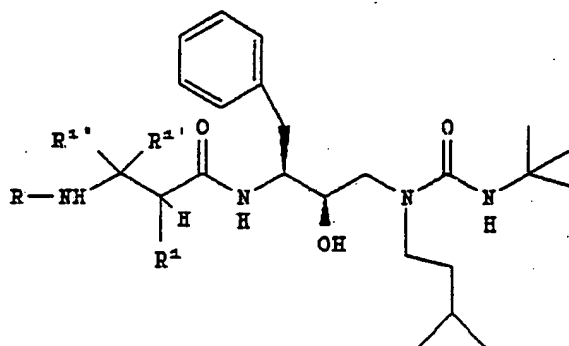
Following generally the procedure set forth in Example 16, the compounds shown in Table 9 were prepared.

TABLE 9

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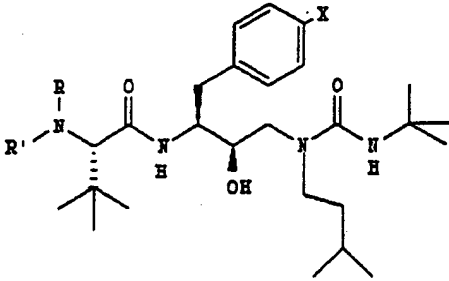
R <sup>1</sup>	R <sup>1'</sup>	R <sup>1''</sup>	R
H	H	H	
H	H	H	
H	CH <sub>3</sub>	H	
H	CH <sub>3</sub>	CH <sub>3</sub>	
H	H	CO <sub>2</sub> CH <sub>3</sub>	
H	H	H	
H	H	H	
H	H	CONH <sub>2</sub>	Cbz
H	H	CONH <sub>2</sub>	2-quinolinylcarbonyl

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Example 19

The procedure set forth below in Example 23 was generally utilized to prepare the compounds shown in Table 10.

TABLE 10

5			
10			
15			
	<u>R</u>	<u>R'</u>	<u>X</u>
20	R=H	R'=H	X=H
	R=Me	R'=Me	X=H
	R=H	R'=Me	X=H
	R=Me	R'=Me	X=F
	R=H	R'=Me	X=F
25	R=Cbz	R'=Me	X=H
	R=H	R'=Bz	X=H
	R+R'= pyrrole*		X=H

\* lle in place of t-butylglycine

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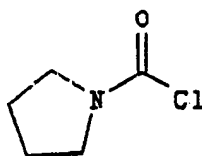
Example 20

This example illustrates preparation of compounds wherein R<sup>4</sup> and R<sup>5</sup> together with N, forms a heterocycloalkyl radical.

35

a) Pyrrolidine carbamoyl chloride.

40



45

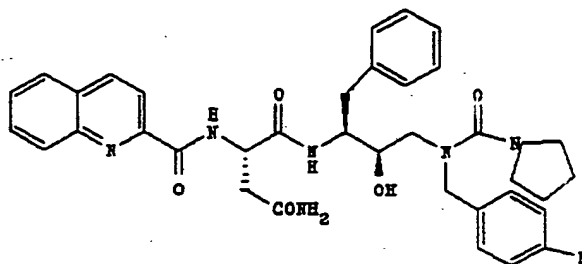
A stirring solution of triphosgene (27.78g, 0.103 mol) in 40 mL toluen was cooled to -20 °C in an ice/salt bath under a blanket of nitrogen and treated with a solution of N-methylmorpholine (27.3 g, 0.27 mol) in 20

50

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mL of toluene dropwise over 1h. This solution was then treated with a solution of pyrrolidine (19.8 g, 0.27 mol) in 30 mL of toluene over a period of 30 m. The solution was allowed to warm to room temperature, filtered and the filtrate concentrated *in vacuo* to give an oil that was purified by vacuum distillation through a 12" Vigreux column to give 20.7g, 56%, bp 58 °C @ 0.6 mm, of pure product.

b) Butanediamide, N<sup>1</sup>-[3-[[[(4-fluorophenyl)methyl]](1-pyrrolidinylcarbonyl)amino]-2-hydroxy-1-(phenylmethyl)propyl]-2-[(2-quinolinylcarbonyl)amino]-[1S[1R\*(R\*),2S\*]]-



A stirring solution of [1S-[1R\*(R\*),2S\*]]-N<sup>1</sup>-[3-[[[(4-fluorophenyl)methyl]amino]-2-hydroxy-1-(phenylmethyl)propyl]-2-[(2-quinolinylcarbonyl)amino]-butanediamide (1.08 g, 1.91 mmol) (prepared as in Example 31) in 7 mL of anhydrous DMF was treated with pyrrolidine carbamoyl chloride (260 mg, 1.95 mmol), 4-dimethylaminopyridine (15 mg), and N-methylmorpholine (380 mg, 3.76 mmol). The solution was stirred at room temperature for 3h and then concentrated *in vacuo* to give a semi-solid that was dissolved in methanol/water ca. 2:1. A solid formed from this solid that was isolated by filtration on a Büchner funnel and washed with water, 5% aq. citric acid and water and air dried to give 130 mg of pure product, TLC on SiO<sub>2</sub> eluting with



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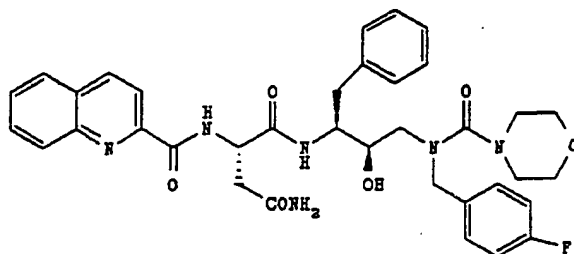
7% methanol in thyl acetate showed one spot with  $R_f=0.64$ , 11%.

c) Butanediarnide,  $N^1$ -[3-[[ (4-fluorophenyl)methyl] (4-morpholinylcarbonyl) amino]-2-hydroxy-1-

5 (phenylmethyl)propyl]-2-[(2-quinolinylcarbonyl) amino]-[1S[1R\*(R\*),2S\*]]-

10

15



20

To a stirring solution of [1S-[1R\*(R\*),2S\*]]- $N^1$ -[3-[[ (4-fluorophenyl)methyl] amino]-2-hydroxy-1-(phenylmethyl)propyl]-2-[(2-quinolinylcarbonyl) amino-  
 25 butanediarnide (520 mg, 0.922 mmol), triethylamine (172 mg, 1.70 mmol), 4-dimethylaminopyridine (50 mg), and morpholino carbamoyl chloride (157.3 mg, 1.05 mmol) in 5 mL of chloroform. The initially heterogeneous mixture was heated to reflux for 6 h. The solution was then  
 30 diluted with additional chloroform, poured into a separatory funnel and washed with 1N  $\text{KHSO}_4$ , sat. aq.  $\text{NaHCO}_3$ , dried over anhyd.  $\text{MgSO}_4$ , filtered, and concentrated *in vacuo* to give a white solid that was purified by column chromatography on  $\text{SiO}_2$  eluting with  
 35 ethanol/ethyl acetate to give 380 mg, 61%, of pure product.

#### Example 21

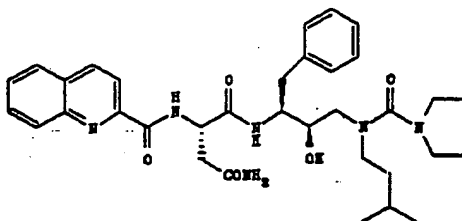
This example illustrates preparation of compounds wherein  $R^4$  and  $R^5$  are both other than H.

40

Butan diamid ,  $N^1$ -[3-[[ (di thylamino)carbonyl] (3-m thylbutyl) amino]-2- hydroxy-1-(ph nylmethyl)pr pyl]-2-[(2-quinolinylcarbonyl) amino]-[1S-[1R\*(R\*),2S\*]]-

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5



- 10 To a stirring solution of [1S-[1R\*(R\*),2S\*]]-N<sup>1</sup>-[3-(methylbutyl)amino]-2-hydroxy-1-(phenylmethyl)propyl]-2-[(2-quinolinylcarbonyl)amino-butane diamide] (119 mg, 0.21 mmol) triethylamine (59 mg, 0.58 mmol), 4-dimethylaminopyridine (9 mg), and diethyl carbamoyl
- 15 chloride (157.3 mg, 1.05 mmol) in 4 mL of chloroform. The mixture was kept at room temperature for 26 h. The solution was then diluted with additional chloroform, poured into a separatory funnel and washed with 1N KHSO<sub>4</sub>, sat. aq. NaHCO<sub>3</sub>, dried over anhyd. MgSO<sub>4</sub>, filtered, and
- 20 concentrated in vacuo to give a white solid that was purified by column chromatography on SiO<sub>2</sub> eluting with methanol/CH<sub>2</sub>Cl<sub>2</sub> to give 20 mg, 15%, of pure product.

#### Example 22

- Following the procedures set forth in Examples
- 25 20 and 21, the compounds listed in Table 11 were prepared.

TABLE 11

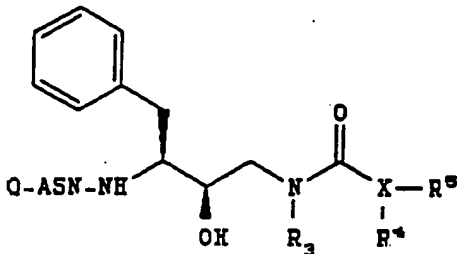
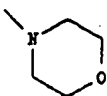
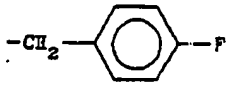
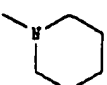
5			
10			
15	$R_3$	$\begin{array}{c} X-R_4 \\   \\ R^5 \end{array}$	$\begin{array}{c} -X-R^5 \\   \\ R^4 \end{array}$
20	$-\text{CH}_2\text{CH}(\text{CH}_3)_2$	$-\text{N}(\text{CH}_3)_2$	
	"	$-\text{N}(\text{CH}_2\text{CH}_3)_2$	
	"	$-\text{N}(\text{CH}(\text{CH}_3)_2)_2$	
25	$-\text{CH}_2\text{CH}_2\text{CH}(\text{CH}_3)_2$	$-\text{N}(\text{CH}_3)_2$	
	"	$-\text{N}(\text{CH}_2\text{CH}_3)_2$	
	"		
30		$-\text{N}(\text{CH}_3)_2$	
		$-\text{N}(\text{CH}_2\text{CH}_3)_2$	
35	"		

TABLE 11 (Cont'd)

5.	$R_3$	$\begin{array}{c} X-R_4 \\   \\ R^5 \end{array}$
10	"	$N(CH_3)(t-Bu)$
	"	
	"	
15	"	
	"	

Example 23

This example illustrates preparation of  
 20 compounds of Formula II where in  $R^1$  is an alkyl group

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ther than an alkyl group of a naturally occurring amino acid side chain. In particular R<sup>1</sup> is a t-butyl group.

Part A:

3-[[[(1,1-dimethylethyl)amino]carbonyl](3-methylbutyl)amino-2(R)-hydroxy-1(S)-[N-(benzyloxycarbonyl)(phenylmethyl)propyl amine] (4.7 gm, 9.7 mmol) was combined with 10% Pd on carbon (200 mg) and conc. HCl (3 mL) in ethanol (35 mL) and hydrogenated at 50 psi of hydrogen for 2.5 h. The reaction mixture was filtered through diatomaceous earth and concentrated on a rotary evaporator to a yellow hygroscopic solid; 3.7 gm, 100%.

Part B:

Butaneamide, 2-[(phenylmethyloxycarbonyl)amino]-N-[3-[[[(1,1-dimethylethyl)amino]carbonyl](3-methylbutyl)amino]-2-hydroxy-1-(phenylmethyl)propyl-3,3-dimethyl-[1S-[1R\*(R\*),25\*]]-

N-Cbz-L-tert-leucine (172 mg, 0.65 mmol) and N-hydroxybenzotriazole (100 mg, 0.65 mmol) in DMF (3 mL) was cooled to 0°C and EDC (115 mg, 0.60 mmol) added. After 45 min the amine from Part A (193 mg, 0.50 mmol) and N-methylmorpholine (60 uL, 0.55 mmol) were added. The reaction was stirred at ambient temperature for 18 h and poured into a solution of 50% saturated NaHCO<sub>3</sub> (25 mL). The solid was collected by suction filtration, washed with water and dried in-vacuo. The solid was chromatographed on SiO<sub>2</sub> using 2% MeOH in CH<sub>2</sub>Cl<sub>2</sub>. The appropriate fractions were pooled and concentrated to afford a white solid; 220 mg, MH<sup>+</sup> 597, TLC (SiO<sub>2</sub>, 2%MeOH/CH<sub>2</sub>Cl<sub>2</sub>) R<sub>f</sub> = .2. CHN requires: C, 68.42, H, 8.78, N, 9.39; found: C, 68.03, H, 8.83, N, 9.33.

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Part C:

Butaneamide, 2-amino-N-[3-[[[(1,1-  
dimethylethyl)amino]carbonyl](3-methylbutyl)amino]-2-  
hydroxy-1-(phenylmethyl)propyl]-3,3-dimethyl-, [1S-  
5 [1R\*(R\*), 2S\*]-

The product from Part B (570 mg, 0.95 mmol) and 4% Pd on carbon (150 mg) in ethanol (30 mL) was hydrogenated at 5 psi for 2.75 h. The reaction mixture was filtered through diatomaceous earth and concentrated  
10 on a rotary evaporator to an oil; 438 mg, 100%.

Part D:

Butaneamide, 2-(acetylamino)-N-[3-[[[(1,1-  
dimethylethyl)amino]carbonyl](3-methylbutyl)amino]-2-  
hydroxy-1-(phenylmethyl)propyl]-3,3-dimethyl-, [1S-  
15 [1R\*(R\*), 2S\*]-

The product from Part C (206 mg, 0.41 mmol) and N-methylmorpholine (45 uL, 0.41 mmol) were dissolved in CH<sub>2</sub>Cl<sub>2</sub> (2.5 mL) and cooled to 0 C. Acetic anhydride (39 uL, 0.41 mmol) was then added and the reaction  
20 stirred 30 min at 0 C, then allowed to warm to ambient temperature and stir for 30 min. The solvent was removed on a rotary evaporator and the residue dissolved in ethanol (2 mL). The ethanolic solution was slowly poured into 50 % saturated NaHCO<sub>3</sub> (20 mL) and stirred  
25 vigorously. The solid was collected by suction filtration and washed with water, 5% citric acid, and again with water; 157 mg, 75%. CHN / 1.5 H<sub>2</sub>O requires: C 63.24, H, 9.67, N, 10.54; found:  
C, 63.40, H, 9.41, N, 10.39.

30

Butaneamide, 2-amino-N-[3-[[[(1,1-  
dimethylethyl)amino]carbonyl](3-methylbutyl)amino]-2-  
hydroxy-1-(phenylmethyl)propyl]-3,3-dimethyl-, [1S-  
[1R\*(R\*), 2S\*]- was also capped with the acyl groups  
35 shown in Table 12.

TABLE 12

Acyl Group (R)	
5	benzyloxycarbonyl
	<u>tert</u> -butoxycarbonyl
	acetyl
10	2-quinoylcarbonyl
	phenoxyacetyl
15	benzoyl
	methyloxaloyl
	pivaloyl
20	trifluoracetyl
	bromoacetyl
25	hydroxyacetyl
	morpholinylacetyl
	N,N-dimethylaminoacetyl
30	N-benzylaminoacetyl
	N-phenylaminoacetyl
35	N-benzyl-N-methylaminoacetyl
	N-methyl-N-(2-hydroxyethyl)aminoacetyl
	N-methylcarbamoyl
40	3-methylbutyryl
	N-isobutylcarbamoyl
45	succinoyl (3-carboxypropionyl)
	carbamoyl
50	

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Example 24A

The procedure described below illustrates preparation of compounds of Formula III.

Propanamide, N-[3-[[[(1,1-dimethylethyl)amino]carbonyl](3-methylbutyl)amino]-2-hydroxy-1-(phenylmethyl)propyl]-2-methyl-3-(2-phenylethylsulfonyl)-, [1S-[1R\*(R\*),2S\*]] and its diastereomer.

Part A

10 A solution of methyl methacrylate (7.25 g, 72.5 mmol) and phenethyl mercaptan (10.0 g, 72.5 mmol) in 100 mL of methanol was cooled in an ice bath and treated with sodium methoxide (100 mg, 1.85 mmol). The solution was stirred under nitrogen for 3 h and then  
15 concentrated in vacuo to give an oil that was taken up in ether and washed with 1 N aqueous potassium hydrogen sulfate, saturated aqueous sodium chloride, dried over anhydrous magnesium sulfate, filtered and concentrated to give 16.83 g, 97.5% of methyl 2-(R,S)-methyl-4-thia-  
20 6-phenyl hexanoate as an oil. TLC on SiO<sub>2</sub> eluting with 20:1 hexane:ethyl acetate (v:v) R<sub>f</sub>=0.41.

Part B

A solution of methyl 2-(R,S)-methyl-4-thia-6-phenyl hexanoate (4.00 g, 16.8 mmol) in 100 mL of  
25 dichloromethane was stirred at room temperature and treated portion wise with meta-chloroperoxybenzoic acid (7.38 g, 39.2 mmol) over approximately 40 m. The solution was stirred at room temperature for 16 h and then filtered and the filtrate washed with saturated  
30 aqueous sodium bicarbonate, 1N sodium hydroxide, saturated aqueous sodium chloride, dried over anhydrous magnesium sulfate, filtered, and concentrated to give 4.50 g, 99% of desired sulfone. The unpurified sulfone was dissolved in 100 mL of tetrahydrofuran and treated  
35 with a solution of lithium hydroxide (1.04 g, 24.5 mmol) in 40 mL of water. The solution was stirred at room temperature for 2 m and then concentrated in vacuo. The residue was then acidified with 1N aqueous potassium



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hydrogen sulfate to pH=1 and then extracted three times with ethyl acetate. The combined ethyl acetate solution was washed with saturated aqueous sodium chloride, dried over anhydrous magnesium sulfate, filtered and concentrated to give a white solid. The solid was taken up in boiling ethyl acetate/hexane and allowed to stand undisturbed whereupon white needles formed that were isolated by filtration and air dried to give 3.38 g, 79% of 2-(R,S)-methyl-3( $\beta$ -phenethylsulfonyl)-propionic acid, mp 91-93°C.

#### Part C

A solution of 2-(R,S)-methyl-3( $\beta$ -phenethylsulfonyl)-propionic acid (166.1 mg, 0.65 mmol), N-hydroxybenzotriazole (HOBT) (146.9 mg, 0.97 mmol), and 1-(3-dimethylaminopropyl)-3-ethylcarbodiimide hydrochloride (EDC) (145.8 mg, 0.75 mmol) in 4 mL of anhydrous dimethylformamide (DMF) cooled to 0°C and stirred under nitrogen for 0.5 h. This solution was then treated with 3-[[[(dimethylethyl)amino]carbonyl](3-methylbutyl)amino-2(R)-hydroxy-1(S)-(phenylmethyl)propylamine (201.9 mg, 0.59 mmol) and stirred at room temperature for 16 h. The solution was poured into 30 mL of 60% saturated aqueous sodium bicarbonate solution. The aqueous solution was then decanted from the organic residue. The organic residue was taken up in dichloromethane and washed with 10% aqueous citric acid, brine, dried over anhydrous magnesium sulfate, filtered and concentrated to give 110.0 mg, 32% of (2R,3S)-3-[N-2-(R)-methyl-3-( $\beta$ -phenethylsulfonyl)propionyl]amido-1-isoamyl-1-(tert-butylcarbamoyl)amino-4-phenyl-2-butanol and (2R,3S)-3-[N-2-(S)-methyl-3-( $\beta$ -phenethylsulfonyl)propionyl]amido-1-isoamyl-1-(tert-butylcarbamoyl)amino-4-phenyl-2-butanol, FAB mass spectrum (MH<sup>+</sup>) = 588. Flash chromatography of the mixture on silica gel eluting with 1:1 hexane:ethyl acetate afforded the separated diastereomers.

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Example 24B

Propanamide, N-[3-[[[(1,1-dimethylethyl)amino]carbonyl](3-methylbutyl)amino]-2-hydroxy-1-(phenylmethyl)propyl]-2-methyl-3-

5 (methylsulfonyl)- [1S-[1R\*(R\*), 2S\*]], and its diastereomer.

Part A

A solution of methyl 2-(bromomethyl)-acrylate (26.4 g, 0.148 mol) in 100 mL of methanol was treated

10 with sodium methanesulfinate (15.1 g, 0.148 mol) portion wise over 10 m at room temperature. The solution was then stirred at room temperature for a period of 1.25 h and the solution concentrated *in vacuo*. The residue was then taken up in water and extracted four times with

15 ethyl acetate. The combined ethyl acetate solution was washed with saturated sodium chloride, dried over anhydrous magnesium sulfate, filtered and concentrated to give a white solid, 20.7 g which was taken up in boiling acetone/methyl tert-butyl ether and allowed to

20 stand whereupon crystals of pure methyl 2-(methylsulfonylmethyl) acrylate 18.0 g, 68% formed, mp 65-68 °C.

Part B

A solution of methyl 2-(methylsulfonylmethyl) acrylate (970 mg, 5.44 mmol) in 15 mL of tetrahydrofuran

25 was treated with a solution of lithium hydroxide (270 mg, 6.4 mmol) in 7 mL of water. The solution was stirred at room temperature for 5 m and then acidified to pH=1 with 1 N aqueous potassium hydrogen sulfate and

30 the solution extracted three times with ethyl acetate. The combined ethyl acetate solution was dried over anhydrous magnesium sulfate, filtered, and concentrated to give 793 mg, 89% of 2-(methylsulfonylmethyl) acrylic acid, mp 147-149 °C.

35 Part C

A solution of 2-(methylsulfonylmethyl) acrylic acid (700 mg, 4.26 mmol) in 20 mL of methanol was charged into a Fisher-Porter bottle along with 10%

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palladium on carbon catalyst under a nitrogen atmosphere. The reaction vessel was sealed and flushed five times with nitrogen and then five times with hydrogen. The pressure was maintained at 50 psig for 16 h and then the hydrogen was replaced with nitrogen and the solution filtered through a pad of celite to remove the catalyst and the filtrate concentrated *in vacuo* to give 682 mg 96% of 2-(R,S)-methyl-3-methylsulfonyl propionic acid.

10 Part D

A solution of 2-(R,S)-methyl-3(methylsulfonyl) propionic acid (263.5 mg, 1.585 mmol), N-hydroxybenzotriazole (HOBT) (322.2 mg, 2.13 mmol), and 1-(3-dimethylaminopropyl)-3-ethylcarbodiimide hydrochloride (EDC) (339.1 mg, 1.74 mmol) in 4 mL of anhydrous dimethylformamide (DMF) cooled to 0°C and stirred under nitrogen for 0.5 h. This solution was then treated with 3-[[[(1,1-dimethylethyl)amino]carbonyl](3-methylbutyl)amino]-2(R)-hydroxy-1(S)-(phenylmethyl)propyl amine (543.5 mg, 1.58 mmol) and stirred at room temperature for 16 h. The solution was poured into 60 mL of 60% saturated aqueous sodium bicarbonate solution. The aqueous solution was then decanted from the organic residue. The organic residue was taken up in dichloromethane and washed with 10% aqueous citric acid, brine, dried over anhydrous magnesium sulfate, filtered and concentrated to give 471.8 mg, 60% of Propanamide, N-[3-[[[(1,1-dimethylethyl)amino]carbonyl](3-methylbutyl)amino]-2-hydroxy-1-(phenylmethyl)propyl]-2-methyl-3-(methylsulfonyl)-, [1S-[1R\*(R\*), 2S\*]]- and its diastereomer.

Example 25

Preparation of Sulfone Inhibitors From L-(+)-S-acetyl-  
35  $\beta$ -mercaptoisobutyric Acid

Part A:

Propanamide, N-[3-[[[(1,1-dimethylethyl)amin ]carbonyl](3-methylbutyl)amino]-2-

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hydroxy-1-(phenylmethyl)propyl]-2-methyl-3-S-acetyl)-  
[1S-[1R\*),2S\*]]-.

A round-bottomed flask was charged with  
(2R,3R)-3-amino-1-isoamyl-1-(tert-butylcarbonyl)amino-  
5 4-phenyl-2-butanol (901.5 mg, 2.575 mmol), L-(+)-S-  
acetyl-b-mercaptopisobutyric acid (164.5 mg, 2.575 mmol),  
1-(3-dimethylaminopropyl)-3-ethylcarbodiimide  
hydrochloride (EDC) (339.1 mg, 1.74 mmol), and 10 mL of  
CH<sub>2</sub>Cl<sub>2</sub> and allowed to stir at room temperature for 16 h.  
10 The solution was concentrated in vacuo and the residue  
taken up in ethyl acetate, washed with 1N KHSO<sub>4</sub> sat. aq.  
NaHCO<sub>3</sub>, brine, dried over anhydrous MgSO<sub>4</sub>, filtered and  
concentrated to give an oil that was purified by radial  
chromatography on SiO<sub>2</sub> eluting with ethyl acetate to give  
15 the pure product, 800 mg, 63%.

Part B:

Propanamide, N-[3-[[[1,1-  
dimethylethyl)amino]carbonyl](3-methylbutyl)amino]-2-  
hydroxy-1-(phenylmethyl)propyl]-2-methyl-3-mercapto)-,  
20 [1S-[1R\*(R\*),2S\*]]-.

A solution of [1S-[1R\*(R\*),2S\*]]- N-[3-  
[[[(1,1-dimethylethyl)amino]carbonyl](3-  
methylbutyl)amino]-2-hydroxy-1-(phenylmethyl)propyl]-2-  
methyl-3-S-acetyl)-propanamide (420 mg, 0.85 mmol) in 10  
25 mL of methanol was treated with anhydrous ammonia for  
ca. 1 m at 0°C. The solution was stirred at that  
temperature for 16 h and then concentrated in vacuo to  
give 380 mg, 99%, of the desired product that was used  
directly in the next step without further purification.

30 Part C:

Propanamide, N-[3-[[[(1,1-  
dimethylethyl)amino]carbonyl](3-methylbutyl)amino]-2-  
hydroxy-1-(phenylmethyl)propyl]-2-methyl-3-S-methyl-,  
[1S-[1R\*(R\*),2S\*]]-.

35 A solution of [1S-[1R\*(R\*),2S\*]]- N-[3-  
[[[(1,1-dimethylethyl)amino]carbonyl](3-  
methylbutyl)amino]-2-hydroxy-1-(phenylmethyl)propyl]-2-  
methyl-3-mercapto)-pr panamide (380 mg, 0.841 mmol) in

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10 mL of dry toluene under nitrogen was treated in rapid succession with 1,8-diazabicycl [5.4.0]undec-7-en , (DBU), (128.1 mg, 0.841 mmol) and iodomethane (119.0 mg, 0.841 mmol). After 0.5 h at room temperature the  
5 reaction was found to be complete and the solution was diluted with ethyl acetate washed with 1N KHSO<sub>4</sub>, sat. aq. NaHCO<sub>3</sub>, brine. After the solution was dried over anhydrous MgSO<sub>4</sub>, filtered and concentrated in vacuo the desired product was obtained as white foam was obtained,  
10 370 mg, 94.5%, that was used directed in the next step.

Part D:

Propanamide, N-[3-[[[(1,1-dimethylethyl)amino]carbonyl](3-methylbutyl)amino]-2-hydroxy-1-(phenylmethyl)propyl]-2-methyl-3-(methylsulfonyl)-, [1S-[1R\*(R\*),2S\*]]-.

A solution of [1S-[1R\*(R\*),2S\*]]-N-[3-[[[(1,1-dimethylethyl)amino]carbonyl](3-methylbutyl)amino]-2-hydroxy-1-(phenylmethyl)propyl]-2-methyl-3-S-methyl)-propanamide (340 mg, 0.73 mmol) and sodium perborate  
20 (500 mg, 3.25 mmol) in 30 mL of glacial acetic acid was warmed to 55°C for 16 h. The solution was concentrated in vacuo and then the residue taken up in ethyl acetate, washed with water, sat. aq. NaHCO<sub>3</sub>, brine, dried over anhydrous MgSO<sub>4</sub>, filtered and concentrated to give the  
25 desired product as a white solid, 350 mg, 96%.

Example 26

The compounds shown in Tables 12 and 13 were prepared generally according to the procedure set forth in Examples 24 and 25.

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TABLE 12

5	
10	
15	<b>R</b>
20	$\text{CH}_3-$ $\text{CH}_3\text{CH}_2-$ $\text{CH}_3\text{CH}_2\text{CH}_2-$
25	$\text{PhCH}_2\text{CH}_2-$ $\text{PhCH}_2-$ $\text{Ph}-$
30	$(\text{CH}_3)_2\text{CH}-$ $\text{HOCH}_2\text{CH}_2-$
35	
40	$\text{C}_6\text{H}_5\text{CH}_2\text{O}-\overset{\text{O}}{\parallel}\text{CCH}_2-$ $\text{H}_2\text{N}-\overset{\text{O}}{\parallel}\text{CCH}_2-$
45	
50	$\text{CH}_2=\text{CH}-\text{CH}_2-$

TABLE 13

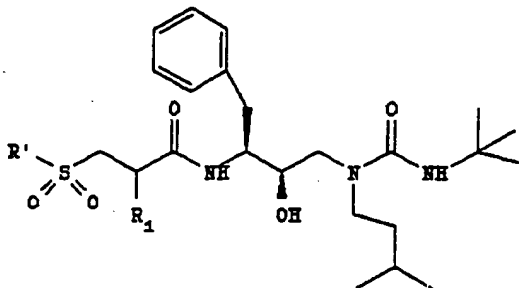
5

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25



The chemical structure shows a central chiral carbon atom bonded to a phenyl ring, a hydrogen atom, a hydroxyl group, and a side chain. The side chain consists of a sulfonamide group (R'-SO<sub>2</sub>-CH<sub>2</sub>-), an amide group (-C(=O)-NH-), and a tert-butyl group. The R<sub>1</sub> group is attached to the carbon atom adjacent to the sulfonamide group.

R'

R<sub>1</sub>

CH<sub>3</sub>

-CH(CH<sub>3</sub>)<sub>2</sub>

Example 27Preparation of 2(S)-methyl-3-(methylsulfonyl)propionic Acid.

- 30 To a solution of 10g of D-(-)-S-benzoyl-b-mercaptioisobutyric acid t-butyl ester in 20 mL of methanol was bubbled in gaseous ammonia at 0°C. The reaction was allowed to then warm to room temperature, stirred overnight and concentrated under reduced
- 35 pressure. The resulting mixture of a solid (benzamide) and liquid was filtered to provide 5.21g of a pale oil which then solidified. This was identified as 2(S)-methyl-3-mercaptopropionic acid t-butyl ester.
- 40 To a solution of 5.21g of 2(S)-methyl-3-mercaptopropionic acid t-butyl ester in 75 mL of toluene at 0°C was added 4.50g of 1,8-diazabicyclo[5.4.0]undec-7-ene and 1.94 mL of methyl iodide. After stirring at room temperature for 2.5 hours, the volatiles were
- 45 removed, ethyl acetate added, washed with dilute hydrochloric acid, water, brine, dried and concentrated

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to afford 2.82g of a pale oil, identified as 2(S)-methyl-3-(thiomethyl)propionic acid t-butyl ester.

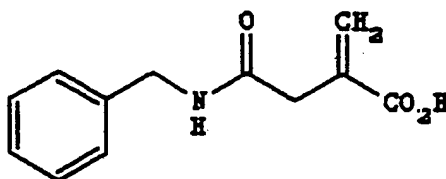
To a solution of 2.82g of 2(S)-methyl-3-(thiomethyl)propionic acid t-butyl ester in 50 mL of acetic acid was added 5.58g of sodium perborate and the mixture heated to 55°C for 17 hours. The reaction was poured into water, extracted with methylene chloride, washed with aqueous sodium bicarbonate, dried and concentrated to afford 2.68g of 2(S)-methyl-3-(methylsulfonyl)propionic acid t-butyl ester as a white solid.

To 2.68g of 2(S)-methyl-3-(methylsulfonyl)propionic acid t-butyl ester was added 20 mL of 4N hydrochloric acid/dioxane and the mixture stirred at room temperature for 19 hours. The solvent was removed under reduced pressure to afford 2.18g of crude product, which was recrystallized from ethyl acetate/hexane to yield 1.44g of 2(S)-methyl-3-(methylsulfonyl)propionic acid as white crystals.

#### Example 28

This example illustrates preparation of compounds of Formula IV wherein t is 1.

4-N-benzyl itaconamide.



A 500 mL three necked round bottomed flask equipped with a dropping funnel, mechanical stirrer, nitrogen inlet and reflux condenser was charged with itaconic anhydride (33.6g, 0.3 mol) and 150 mL of toluene. This solution was added a solution of benzylamine (32.1g, 0.3 mol) in 50 mL of toluene dropwise over 30 min at room temperature.



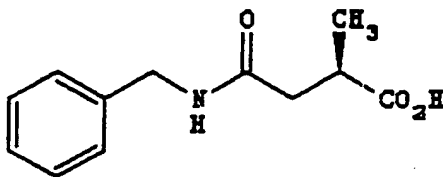
-87-

The solution was stirred at this temperature an additional 3h and then the solid product isolated by filtration on a Büchner funnel. The crude product, 64.6g 98%, was recrystallized from 300 mL of isopropyl alcohol to give after two crops 52.1g, 79% of pure product, mp 149-150 °C

**2(R)-Methyl 4-N-benzyl succinamide.**

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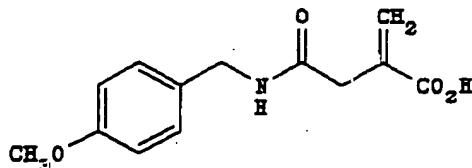
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A large Fisher-Porter bottle was charged with the acid from the above reaction (10.95g, 0.05 mol), rhodium (R,R)-DiPAMP (220mg, 0.291 mmol) and 125 mL of degassed methanol. The solution was then hydrogenated at 40 psig for 16h at room temperature. After the hydrogen uptake ceased, the vessel was opened and the solution concentrated in vacuo to give a yellow solid, 11.05g, 100%. The product was then taken up in absolute ethanol and allowed to stand whereupon crystals of the desired product formed, 7.98g, 72%, mp 127-129 °C [α]<sub>D</sub> 25 °C = +14.9° (c=1.332, EtOH), <sup>1</sup>H nmr (CDCl<sub>3</sub>) 300MHz 7.30(m, 5H), 6.80(brs, 1H), 4.41(d, J=5.8Hz, 2H), 2.94(m, 1H), 2.62(dd, J=8.1, 14.9Hz, 1H), 2.33(dd, J=5.5, 14.9Hz, 1H), 1.23(d, J=7.2Hz, 3H).

**4-N(4-methoxybenzyl)itaconamide.**

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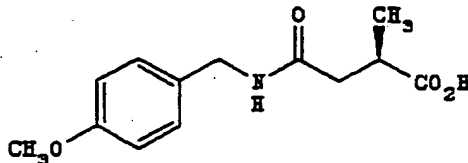
-88-

A 500 mL three necked round bottomed flask equipped with a dropping funnel, mechanical stirrer, nitrogen inlet and reflux condenser was charged with itaconic anhydride (44.8g, 0.4 mol) and 150 mL of toluene. This solution  
5 was added a solution of 4-methoxybenzylamine (54.8g, 0.4 mol) in 50 mL of toluene dropwise over 30 min at room temperature. The solution was stirred at this temperature an additional 2h and then the solid product isolated by filtration on a Büchner funnel. The crude  
10 product was recrystallized from ethyl acetate/ethanol to give after two crops 64.8g, 65% of pure product, mp 132-134 °C, <sup>1</sup>H nmr (CDCl<sub>3</sub>) 300MHz 7.09(d, J=9.1Hz, 2H), 6.90(brt, J=5.9Hz, 1H), 6.74(d, J=9.1Hz, 2H), 6.22(s, 1H), 5.69(s, 1H), 4.24(d, J=5.9Hz, 2H), 3.69(s, 3H),  
15 3.15(s, 2H). <sup>13</sup>C nmr (CDCl<sub>3</sub>) 170.52, 169.29, 159.24, 135.61, 131.08, 129.37, 128.97, 114.36, 55.72, 43.37, 40.58.

**2(R)-Methyl 4-N(4-methoxybenzyl)succinamide.**

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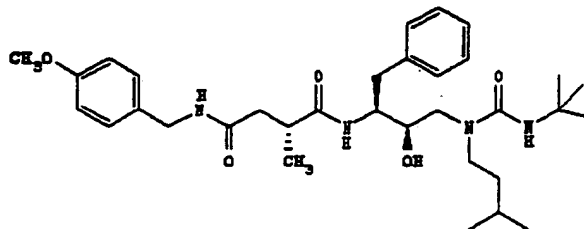


A large Fisher-Porter bottle was charged with the acid  
30 from the above reaction (5.00 g, 0.02 mol), rhodium (R,R)-DiPAMP (110 mg, 0.146 mmol) and 50 mL of degassed methanol. The starting acid was not completely soluble initially, but as the reaction progressed the solution became homogeneous. The solution was then hydrogenated  
35 at 40 psig for 16h at room temperature. After the hydrogen uptake ceased, the vessel was opened and the solution concentrated in vacuo to give a yellow solid. The crude product was then taken up in ethyl acetate and washed three times with sat. aq. NaHCO<sub>3</sub> solution. The  
40 combined aqueous extracts were acidified to pH=1 with 3 N HCl and then extracted three times with ethyl acetate.

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The combined thyl acetat extracts were wash d with brine, dri d over anhyd.  $\text{MgSO}_4$ , filtered and concentrated to give the expected product as a white solid, 4.81g, 95%. This material was recrystallized from a mixture of methyl ethyl ketone/hexane to give 3.80g, 75% of pure product,  $[\alpha]_D^{25} = +11.6^\circ$  ( $c=1.572$ , MeOH).  $^1\text{H}$  nmr ( $\text{CDCl}_3$ ) 300MHz 11.9(brs, 1H), 7.18(d,  $J=9.2\text{Hz}$ , 2H), 6.82(d,  $J=9.2\text{Hz}$ , 2H), 6.68(brt,  $J=5.6\text{Hz}$ , 1H), 4.33(d,  $J=5.6\text{Hz}$ , 2H), 3.77(s, 3H), 2.92(ddq,  $J=7.9$ , 5.4, 7.3Hz, 1H), 2.60(dd,  $J=5.4$ , 15.0Hz, 1H), 2.30(dd,  $J=7.9$ , 15.0Hz, 1H), 1.22(d,  $J=7.3\text{Hz}$ , 3H).

Butanediamide, N'-[3-[[[(1,1-dimethylethyl)amino]carbonyl](3-methylbutyl)amino]-2-hydroxy-1-(phenylmethyl)propyl]-N-4-methoxyphenylmethyl-2-methyl, [1S-[1R\*(2R\*),2S\*]]-

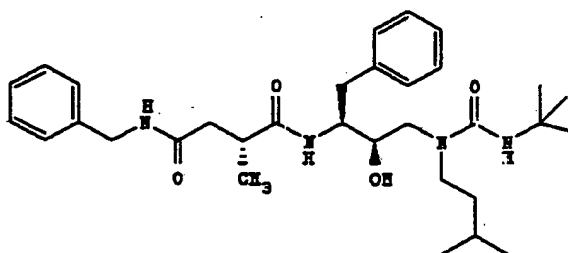


A 50 mL round bottomed flask was charged with 2(R)-methyl 4-N(4-methoxybenzyl)succinamide (588 mg, 2.35 mmol), N-hydroxybenzotriazole (511 mg, 3.34 mmol) and 6 mL of DMF. The solution was cooled to  $0^\circ\text{C}$  and treated with 1-(3-dimethylaminopropyl)-3-ethylcarbodiimide hydrochloride (502 mg, 2.62 mmol) for 20 m. A solution of (2R,3S)-3-amino-1-(3-methylbutyl)-1-[(1,1-dimethylethyl)amino]carbonyl)-4-phenyl-2-butanol (782 mg, 2.24 mmol) in 2 mL of DMF was added and the solution stirred at room temperature for a period of 24 h. The solution was concentrated in vacuo and poured into 50 mL

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f 50% sat. aq.  $\text{NaHCO}_3$ , the aqueous phase was extracted with  $\text{CH}_2\text{Cl}_2$ . The organic phase was washed with 5% citric acid,  $\text{NaHCO}_3$ , brine, dried over anhyd.  $\text{MgSO}_4$ , filtered and concentrated to give an oil that was purified by radial chromatography on  $\text{SiO}_2$  eluting with hexane/ethyl acetate to give 790 mg, 59% of pure product as a white foam.

Butanediamide, N'-[3-[[[(1,1-dimethylethyl)amino]carbonyl](3-methylbutyl)amino]-2-hydroxy-1-(phenylmethyl)propyl]-N-phenylmethyl-2-methyl, [1S-[1R\*(2R\*),2S\*]]-



A 50 mL round bottomed flask was charged with 2(R)-methyl 4-N-(benzyl) succinamide (243 mg, 1.1 mmol), N-hydroxybenzotriazole (213 mg, 1.39 mmol) and 3 mL of DMF. The solution was cooled to 0° C and treated with 1-(3-dimethylaminopropyl)-3-ethylcarbodiimide hydrochloride (228 mg, 1.17 mmol) for 20 m. A solution of (2R,3S)-3-amino-1-(3-methylbutyl)-1-[(1,1-dimethylethyl)amino]carbonyl-4-phenyl-2-butanol (327 mg, 0.95 mmol) in 2 mL of DMF was added and the solution stirred at room temperature for a period of 24 h. The solution was concentrated in vacuo and poured into 50 mL of 50% sat. aq.  $\text{NaHCO}_3$ , the aqueous phase was extracted with  $\text{CH}_2\text{Cl}_2$ . The organic phase was washed with 5% citric acid,  $\text{NaHCO}_3$ , brine, dried over anhyd.  $\text{MgSO}_4$ , filtered and concentrated to give an oil that was purified by

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flash chromatography on SiO<sub>2</sub> eluting with hexane/ thyl acetate to give 370 mg, 70% of pure product as a white foam.

Example 29

5                   Following the procedure generally as set forth in Example 28, as well as in Examples 31-45, the compounds shown in Table 14 were prepared.

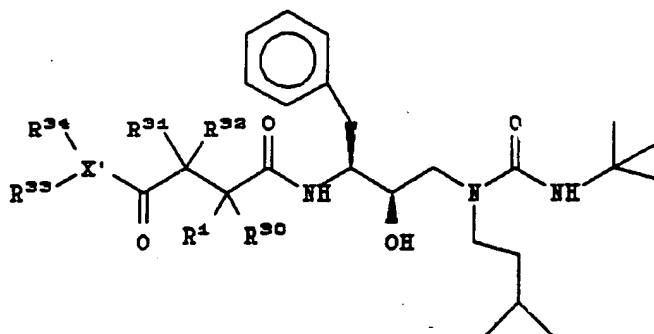
TABLE 14

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	R <sup>1</sup>	R <sup>30</sup>	R <sup>31</sup>	R <sup>32</sup>	X'	R <sup>33</sup>	R <sup>34</sup>
30	H	H	H	H	N	H	H
	H	H	H	H	O	H	-
	H	H	H	H	O	CH <sub>3</sub>	-
35	CH <sub>3</sub>	H	H	H	N	H	H
	CH <sub>3</sub>	H	H	H	O	H	-
	H	H	CH <sub>3</sub>	H	N	H	H
40	H	H	CH <sub>3</sub>	H	O	H	-
	CH <sub>3</sub>	CH <sub>3</sub>	H	H	N	H	H
	CH <sub>3</sub>	CH <sub>3</sub>	H	H	O	H	-
45	CH <sub>3</sub>	CH <sub>3</sub>	H	H	O	CH <sub>2</sub> C <sub>6</sub> H <sub>4</sub> OCH <sub>3</sub>	-
	H	H	CH <sub>3</sub>	CH <sub>3</sub>	N	H	H
	H	H	CH <sub>3</sub>	CH <sub>3</sub>	O	H	-
50	H	H	CH <sub>3</sub>	CH <sub>3</sub>	O	CH <sub>2</sub> C <sub>6</sub> H <sub>4</sub> OCH <sub>3</sub>	-
	H	H	CH <sub>3</sub>	CH <sub>3</sub>	O	CH <sub>2</sub> C <sub>6</sub> H <sub>4</sub> OCH <sub>3</sub>	-

TABLE 14 (C nt'd)

	R <sup>1</sup>	R <sup>30</sup>	R <sup>31</sup>	R <sup>32</sup>	X'	R <sup>33</sup>	R <sup>34</sup>
5	CH <sub>3</sub>	H	CH <sub>3</sub>	H	N	H	H
	CH <sub>3</sub>	H	CH <sub>3</sub>	H	N	H	CH <sub>3</sub>
	CH <sub>3</sub>	H	CH <sub>3</sub>	H	N	CH <sub>3</sub>	CH <sub>3</sub>
	CH <sub>3</sub>	H	CH <sub>3</sub>	H	O	H	-
10	CH <sub>3</sub>	H	CH <sub>3</sub>	H	N	H	-CH <sub>2</sub> C <sub>6</sub> H <sub>5</sub> OCH <sub>3</sub>
	OH	H	H	H	N	H	H
	OH	H	H	H	O	H	-
	H	H	OH	H	N	H	H
	H	H	OH	H	O	H	-
15	CH <sub>2</sub>	H	H	H	N	H	H
	CH <sub>2</sub> C(O)NH <sub>2</sub> H		H	H	N	H	H
20	CH <sub>2</sub> C(O)NH <sub>2</sub> H		H	H	O	H	-
25	CH <sub>2</sub> C(O)NH <sub>2</sub> H		H	H	O	CH <sub>3</sub>	-
	CH <sub>2</sub> Ph	H	H	H	N	H	H
30							

Example 30

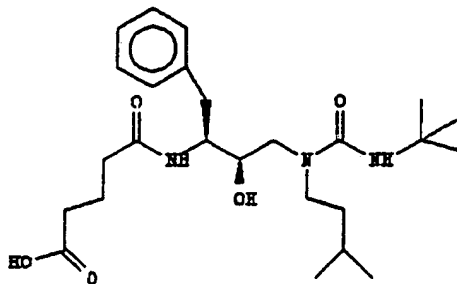
Following the procedure generally as set forth in Example 28, as well as Examples 31-45, the compounds shown in Table 15 were prepared.

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TABLE 15

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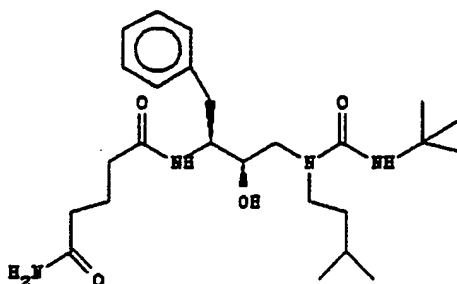
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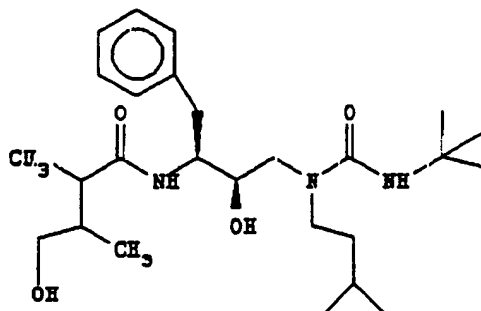
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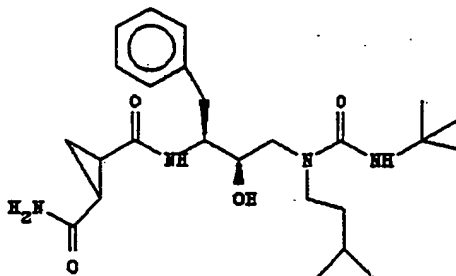
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**TABLE 15 (Cont'd)**

### Example 31

20 Preparation of 3(S)-[N-(2-quinolinylcarbonyl)-L-  
asparaginyl]amino-2(R)-hydroxy-4-phenylbutylamine, N-  
(3-methylbutyl).

**Part A:**

Preparation of N-3(S)-(Benzyloxycarbonyl)-amino-2(R)-hydroxy-4-phenylbutylamine, N-(3-methylbutyl). A solution of 20g (67 mmol) of N-benzyloxycarbonyl-3(S)-amino-1,2-(S)-epoxy-4-phenylbutane in 140 mL of isopropyl alcohol was treated with 83g (952 mmol) of isoamylamine and refluxed for one hour. The solution was cooled, concentrated, hexane added and the resulting solid filtered to afford 22.4g of the desired product.

**Part B:**

Preparation of N-3(S)-(Benzyloxycarbonyl)-  
35 amino-2(R)-hydroxy-4-phenylbutylamine, N-(3-  
methylbutyl)-N-(t-butyloxycarbonyl). To a solution of  
22.4g (58.3 mmol) of product from Part A above, 6.48g  
(64.1 mmol) of triethylamine and 150 mg of N,N-dimethyl-  
4-aminopyridine in 200 mL of tetrahydrofuran at 0°C was  
40 added 12.7g (58.3 mmol) of di-t-butylpyrocarbonate in 10  
mL of THF. After 3.5 hours at room temperature, the  
volatiles were removed, ethyl acetate added and washed  
with 5% citric acid, saturated NaHCO<sub>3</sub>, dried and concentrated



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to afford 30g of crude product. Chromatography on silica gel using 20% ethyl acetate/hexane afforded 22.5g (79%) of the desired product.

Part C:

5 Preparation of N-3(S)-[N-benzyloxycarbonyl-L-asparaginyl]amino-2(R)-hydroxy-4-phenylbutylamine, N-(3-methylbutyl)-N-(t-butyloxycarbonyl). A solution of 22.5g of product from Part B above in 200 mL of ethanol was hydrogenated over 5.9g of 10% palladium-on-carbon  
10 under 50 psig hydrogen for one hour. The catalyst was filtered and the solvent removed under reduced pressure to afford 15.7g of free amine. This was dissolved in 130 mL of DMF and 4.54g (44.9 mmol) of N-methylmorpholine was added to a mixture of 13.3g (49.9  
15 mmol) N-benzyloxy-carbonyl-L-asparagine, 11.5g (74.9 mmol) of N-hydroxybenzotriazole and 10.5g (54.9 mmol) of EDCI in 120 mL of DMF at 0°C, which had been preactivated for one hour prior to the addition. The mixture was stirred for 2 hours at 0°C and then for 12  
20 hours at room temperature. The reaction was poured into 1L of saturated aqueous sodium bicarbonate, the solid collected, dissolved in ethyl acetate, washed with water, saturated sodium bicarbonate, 5% citric acid and brine, dried and concentrated to afford 16.7g of the  
25 desired product.

Part D:

Preparation of N-3(S)-[N-(2-quinolinylcarbonyl)-L-asparaginyl]amino-2(R)-hydroxy-4-phenylbutylamine, N-(3-methylbutyl)-N-(t-butyloxycarbonyl). A solution of 16.7g (28.0 mmol) of product from Part C in 250 mL of methanol was  
30 hydrogenated over 6.0g of 10% palladium-on-carbon and under 50 psig hydrogen for one hour. The catalyst was filtered and the solution concentrated to afford 10.0g of free amine. This was dissolved in 100 mL of methylene chloride, 4.35g (43 mmol) of N-methylmorpholine was added followed by 5.53g (20.5

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mmol) of quinoline-2-carboxylic acid, N-hydroxysuccinimide ester. This was stirred at room temperature overnight, the solvent removed, ethyl acetate added and washed with 5% citric acid, saturated sodium bicarbonate, brine, dried and concentrated to afford 14g of crude product. Recrystallization from ethyl acetate and hexane afforded 10.5g (83%) of desired product.

10 Part E:

Preparation of N-3(S)-[N-(2-quinolinyl-carbonyl)-L-asparaginy]amino-2(R)-hydroxy-4-phenylbutylamine, N-(3-methylbutyl). To 80 mL of 4N hydrochloric acid in dioxane was added 9.17g (14.8 mmol) of product from Part D above. After one hour, the product becomes gummy. The solvents were removed, diethyl ether added and removed and the residue dissolved in 20 mL of methanol. This solution was added to 400 mL of saturated aqueous sodium bicarbonate, the solids collected, washed with acetone and hexane and dried in vacuo over  $P_2O_5$  to afford 4.75g of the desired product.

Example 32APreparation of Benzyl 2,2,3(R)-trimethylsuccinate25 Part A:

Preparation of Methyl (S)-lactate, 2-methoxy-2-propyl ether. To a mixture of methyl(s)-(-)-lactate (13.2g, 100 mmol) and, 2-methoxypropene (21.6g, 300 mmol) in  $CH_2Cl_2$  (150 ml) was added  $POCl_3$  (7 drops) at r.t. and the resulting mixture was stirred at this temperature for 16 hours. After the addition of  $Et_3N$  (10 drops), the solvents were removed in vacuo to give 20.0g of (98%) desired product.

35 Part B:

Preparation of 2(S)-hydroxypropional, 2-methoxy-2-propyl ether. The solution of compound from Part A (20.0g) in  $CH_2Cl_2$  (100 ml) was added DIBAL (65 ml

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of 1.5M solution in toluene, 97.5 mmol) dropwise at -78°C for 45 min., then stirring was continued at the temperature for another 45 min. To this cold solution was added MeOH (20 ml), saturated NaCl solution (10 ml) and allowed the reaction mixture to warm up to r.t. and diluted with ether (200 ml), MgSO<sub>4</sub> (150g) was added and stirred for another 2 h. The mixture was filtered and the solid was washed twice with ether. The combined filtrates were rotavaped to afford 11.2g (78%) of the desired aldehyde.

#### Part C:

Preparation of 2(S)-hydroxy-cis-3-butene, 2-methoxy-2-propyl ether. To a suspension of ethyltriphenylphosphonium bromide (28g, 75.5 mmol) in THF (125 ml) was added KN (TMS)<sub>2</sub> (15.7g, 95%, 75 mmol) in portions at 0°C and stirred for 1 h at the temperature. This red reaction mixture was cooled to -78°C and to this was added a solution of aldehyde from Part B (11g, 75 mmol) in THF (25 ml). After the addition was completed, the resulting reaction mixture was allowed to warm up to r.t. and stirred for 16 h. To this mixture was added saturated NH<sub>4</sub>Cl (7.5 ml) and filtered through a pad of celite with a thin layer of silica gel on the top. The solid was washed twice with ether. The combined filtrates were concentrated in vacuo to afford 11.5g of crude product. The purification of crude product by flash chromatography (silica gel, 10:1 Hexanes/EtoAc) affording 8.2g (69%) pure alkene.

#### Part D:

Preparation of 2(S)-hydroxy-cis-3-butene. A mixture of alkene from Part C (8.2g) and 30% aqueous acetic acid (25 ml) was stirred at r.t. for 1 hour. To this mixture was added NaHCO<sub>3</sub> slowly to the pH ~ 7, then extracted with ether (10 ml x 5). The combined ether solutions were dried (Na<sub>2</sub>SO<sub>4</sub>) and filtered. The filtrate was distilled to remove the ether to give 2.85g (64%) pure alcohol, m/e=87(M+H).

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Part E:

Preparation of 2,2,3-trimethyl-hex-(trans)-4-enoic acid. To a mixture of alcohol from Part D (2.5g, 29 mmol) and pyridine (2.5 ml) in  $\text{CH}_2\text{Cl}_2$  (60 ml) was added isobutyryl chloride (3.1g, 29 mmol) slowly at 0°C. The resulting mixture was stirred at r.t. for 2 hours then washed with  $\text{H}_2\text{O}$  (30 ml x 2) and sat. NaCl (25 ml). The combined organic phases were dried ( $\text{Na}_2\text{SO}_4$ ), concentrated to afford 4.2g (93%) ester 2(S)-hydroxy-cis-3-butenyl isobutyrate. This ester was dissolved in THF (10 ml) and was added to a 1.0M LDA soln. (13.5 ml of 2.0M LDA solution in THF and 13.5 ml of THF) slowly at -78°C. The resulting mixture was allowed to warm up to r.t. and stirred for 2 h and diluted with 5% NaOH (40 ml). The organic phase was separated, the aqueous phase was washed with  $\text{Et}_2\text{O}$  (10 ml). The aqueous solution was collected and acidified with 6N HCl to pH - 3. The mixture was extracted with ether (30 ml x 3). The combined ether layers were washed with sat. NaCl (25 ml), dried ( $\text{Na}_2\text{SO}_4$ ) and concentrated to afford 2.5g (60%) of desired acid,  $m/e=157(M+H)$ .

Part F:

Preparation of benzyl 2,2,3(S)-trimethyl-trans-4-hexenoate. A mixture of acid from Part E (2.5g, 16 mmol), BnBr (2.7g, 15.8 mmol),  $\text{K}_2\text{CO}_3$  (2.2g, 16 mmol), NaI (2.4g) in acetone (20 ml) was heated at 75°C (oil bath) for 16 h. The acetone was stripped off and the residue was dissolved in  $\text{H}_2\text{O}$  (25 ml) and ether (35 ml). The ether layer was separated, dried ( $\text{Na}_2\text{SO}_4$ ) and concentrated to afford 3.7g (95%) of benzyl ester,  $m/e=247(M+H)$ .

Part G:

Preparation of benzyl 2,2,3(R)-trimethylsuccinate. To a well-stirred mixture of  $\text{KMnO}_4$  (5.4g, 34, 2 mmol),  $\text{H}_2\text{O}$  (34 ml),  $\text{CH}_2\text{Cl}_2$  (6 ml) and benzyltriethylammonium chloride (200 mg) was added a solution of ester from Part F (2.1g, 8.54 mmol) and acetic acid (6 ml) in  $\text{CH}_2\text{Cl}_2$  (28 ml) slowly at 0°C. The

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resulting mixture was stirred at the temperature for 2 h then r.t. for 16 h. The mixture was cooled in an ice-water bath, to this was added 6N HCl (3 ml) and solid NaHSO<sub>3</sub> in portions until the red color disappeared. The clear solution was extracted with CH<sub>2</sub>Cl<sub>2</sub> (30 ml x 3). The combined extracts were washed with sat. NaCl solution, dried (Na<sub>2</sub>SO<sub>4</sub>) and concentrated to give an oil. This oil was dissolved in Et<sub>2</sub>O (50 ml) and to this was added sat. NaHCO<sub>3</sub> (50 ml). The aqueous layer was separated and acidified with 6N HCl to pH ~ 3 then extracted with Et<sub>2</sub>O (30 ml x 3). The combined extracts were washed with sat. NaCl solution (15 ml), dried (Na<sub>2</sub>SO<sub>4</sub>) and concentrated to afford 725 mg (34%) of desired acid, benzyl 2,2,3(R)-trimethylsuccinate, m/e=251(M+H).

Example 32BPart A:

Preparation of Butanediamide, N'-[3-[[[(1,1-dimethylethyl)amino]carbonyl](3-methylbutyl)amino]-2-hydroxy-1-(phenylmethyl)propyl]-2,3,3-trimethyl-1S-, [1R\*(2S\*),2S\*]]-

To a well-stirred solution of benzyl 2,2,3(R)-trimethylsuccinate (225 mg, 0.9 mmol) in DMF (1.0 ml) was added HOBt (230 mg, 1.5 mmol). The clear reaction mixture was then cooled to 0°C, to this was added EDC (210 mg, 1.1 mmol) and stirred for 1 h at the temperature. To this cold mixture was added a powder of (350 mg, 1.0 mmol) and DMF (0.5 ml). The resulting reaction mixture was stirred for 2 h at 0°C and 16 h at r.t. After the removal of DMF (≤ 40°C), a solution of 60% sat. NaHCO<sub>3</sub> (10 ml) was added. This mixture was extracted with EtOAc (10 ml x 2). The extracts were combined and washed with sat. NaHCO<sub>3</sub> (10 ml x 2), 5% citric acid (10 ml x 2), H<sub>2</sub>O (10 ml), sat. NaCl (10 ml) and dried (Na<sub>2</sub>SO<sub>4</sub>) then concentrated to afford 512 mg (98%) of desired product Butanoic Acid, 4-[[3-[[[(1,1-dimethylethyl)amino]carbonyl](3-methylbutyl)amino]-2-hydroxy-1-(phenylmethyl)propyl]amino]-2,2,3-trimethyl-

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4-oxo, [1S-[1R\*(3S\*),2S ]]-benzyl ester as a white solid, m/e=582(M+H).

Part B:

A mixture of benzyl ester from Part A (480 mg, 0.825 mmol), 10% Pd/C (450 mg) in MeOH (25 ml) was hydrogenated (H<sub>2</sub>, 50 psi) for 1/2 h at r.t. The mixture was filtered and the solid was washed with MeOH (10 ml). The collected filtrates were concentrated to afford a crude acid as a white solid. The crude acid was dissolved in Et<sub>2</sub>O-EtOAc (10:1, 25 ml) and the solution was washed with sat. NaHCO<sub>3</sub> (25 ml) then 5% NaOH (10 ml). The combined aqueous layers were cooled to 0°C and acidified with concentrated HCl (CO<sub>2</sub>) to pH ~ 1 then extracted with Et<sub>2</sub>O-EtOAc (10:1, 25 ml x 3). The combined extracts were washed with sat. NaCl (15 ml), dried (Na<sub>2</sub>SO<sub>4</sub>) and concentrated to afford 307 mg (75.7%) of pure acid Butanoic acid, 4-[[3-[[[(1,1-dimethylethyl)amino]carbonyl](3-methylbutyl)amino]-2-hydroxy-1-(phenylmethyl)propyl]amino]-2,2,3-trimethyl-4-oxo-, [1S-[1R\*(3S\*),2S\*]]-, as a white solid, m/e=491(M+H).

Part C:

Butanoic acid, 4-[[3-[[[(1,1-dimethylethyl)amino]carbonyl](3-methylbutyl)amino]-2-hydroxy-1-(phenylmethyl)propyl]amino]-2,2,3-trimethyl-4-oxo-, [1S-[1R\*(3S\*),2S\*]]-, as a white solid, m/e=491(M+H).

To a well-stirred solution of the acid from Part B (245 mg, 0.5 mmol) in DMF (0.5 ml) was added HOBt (153 mg, 1.0 mmol) and EDC (143 mg, 0.75 mmol) at 0°C. After stirring at 0°C for 2 h, NH<sub>4</sub>OH (0.63 ml of 28% NH<sub>4</sub>OH, 5 mmol) was added and stirred at 0°C for 2 h, r.t. for 16 h. The removal of DMF (≤ 40°C) gave a white solid. The purification of the crude product by flash chromatography (silica gel, 5% MeOH/CH<sub>2</sub>Cl<sub>2</sub>) gave 172 mg (70%) of pure amide as a white solid, m/e=491(M+H).

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Example 33Preparation of methyl 2,2-dimethyl-3-methyl succinate,  
(R) and (S) isomers.Part A:

5 Preparation of methyl 2,2-dimethyl-3-oxo-  
butanoate. A 250 ml RB flask equipped with magnetic  
stir bar and N<sub>2</sub> inlet was charged with 100 ml dry THF and  
4.57g (180 mmol) of 95% NaH. The slurry was cooled to -  
20°C and 10g (87 mmol) methyl acetoacetate was added  
10 dropwise followed by 11.3 ml (181 mmol) CH<sub>3</sub>I. The  
reaction was stirred at 0°C for 2 hours and let cool to  
room temperature overnight. The reaction was filtered  
to remove NaI and diluted with 125 ml Et<sub>2</sub>O. The organic  
phase was washed with 1x100 l 5% brine, dried and  
15 concentrated in vacuo to a dark golden oil that was  
filtered through a 30g plug of silica gel with hexane.  
Concentration in vacuo yielded 10.05g of desired methyl  
ester, as a pale yellow oil, suitable for use without  
further purification.

20 Part B:

Preparation of methyl 2,2-dimethyl-3-oxo-  
(trifluoromethanesulfonate)-but-3-enoate. A 250 ml RB  
flask equipped with magnetic stir bar and N<sub>2</sub> inlet was  
charged with 80 mL by THF and 5.25 ml (37.5 mmol)  
25 diisopropylamine was added. The solution was cooled  
to -25°C (dry ice/ethylene glycol) and 15 ml (37.5 mmol)  
of 2.5 M n-BuLi in hexanes was added. After 10 minutes  
a solution of 5g (35 mmol) 1 in 8 ml dry THF was added.  
The deep yellow solution was stirred at -20°C for 10  
30 min. then 12.4g N-phenyl  
bis(trifluoromethanesulfonimide) (35 mmol) was added.  
The reaction was stirred @ -10°C for 2 hours,  
concentrated in vacuo and partitioned between ethyl  
acetate and sat. NaHCO<sub>3</sub>. The combined organic phase was  
35 washed with NaHCO<sub>3</sub>, brine and conc. to an amber oil that  
was filtered through 60g silica gel plug with 300 mL 5%  
ethyl acetate/hexane. Conc. in vacuo yielded 9.0g light  
yellow oil that was diluted with 65 ml ethyl acetate and

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wash d with 2x50 ml 5% aq  $K_2CO_3$ , 1x10 mL brine, dried over  $Na_2SO_4$  and conc. in vacuo to yield 7.5g (87%) vinyl triflate, (m/e=277(M+H)) suitable for use without further purification.

5 Part C:

Preparation of methyl 2,2-dimethyl-3-carboxyl-but-3-enoate. A 250 ml Fisher Porter bottle was charged with 7.5g (27 mmol) of compound prepared in B, 50 ml dry DMF, 360 mg (1.37 mmol) triphenyl phosphine and 155 mg (.69 mmol)  $Pd(II)(OAc)_2$ . The reaction mixture was purged twice with  $N_2$  then charged with 30 psi CO. Meanwhile a solution of 20 ml dry DMF and 7.56 ml (54 mmol)  $NEt_3$  was cooled to 0°C to this was added 2.0g (43 mmol) of 99% formic acid. The mixture was swirled and added to the vented Fisher Porter tube. The reaction vessel was recharged to 40 psi of CO and stirred 6 hours @ room temperature. The reaction mixture was concentrated in vacuo and partitioned between 100 mL of ethyl acetate and 75 mL 5% aq  $K_2CO_3$ . The aqueous phase was washed with 1x40 mL additional ethyl acetate and then acidified with conc. HCl/ice. The aqueous phase was extracted with 2x70 mL of ethyl acetate and the organics were dried and conc. to yield 3.5g (75%) white crystals, mp 72-75°C, identified as the desired product (m/e=173(M+H)).

Part D:

Preparation of methyl 2,2-dimethyl-3-methylsuccinate, isomer #1. A steel hydrogenation vessel was charged with 510 mg (3.0 mmol) acrylic acid, from Part C, and 6 mg Ru (acac) $_2$  (R-BINAP) in 10 ml degassed MeOH. The reaction was hydrogenated at 50 psi/room temperature for 12 hours. The reaction was then filtered through celite and conc. to 500 mg clear oil which was shown to be a 93:7 mixture of isomer #1 and #2, respectively as determined by GC analysis using a 50 M  $\beta$ -cycl dextrin column: 150°C - 15 min. then ramp 2°C/min.; isomer #1, 17.85 min., isomer #2, 18-20 min.



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Part E:

Preparation of methyl 2,2-dimethyl-3-methylsuccinate, Isomer #2. A steel hydrogenation vessel was charged with 500 mg (2.9 mmol) acrylic acid, 5 Part C, and 6 mg Ru(OAc)(acac)(S-BINAP) in 10 ml degassed MeOH. The reaction was hydrogenated at 50 psi/room temperature for 10 hours. The reaction was filtered through celite and concentrated in vacuo to yield 490 mg of product as a 1:99 mixture of isomers #1 10 and #2, respectively, as determined by chiral GC as above.

Example 34

Preparation of 3-[[[(1,1-dimethylethyl)amino]carbonyl](3-methylbutyl)amino]-2(R)-hydroxy-1(S)-(phenylmethyl)propylamine, 1. 15

Part A:

To a solution of 75.0g (0.226 mol) of N-benzyloxycarbonyl-L-phenylalanine chloromethyl ketone in 20 a mixture of 807 mL of methanol and 807 mL of tetrahydrofuran at -2°C, was added 13.17g (0.348 mol, 1.54 equiv.) of solid sodium borohydride over one hundred minutes. The solvents were removed under reduced pressure at 40°C and the residue dissolved in 25 ethyl acetate (approx. 1L). The solution was washed sequentially with 1M potassium hydrogen sulfate, saturated sodium bicarbonate and then saturated sodium chloride solution. After drying over anhydrous magnesium sulfate and filtering, the solution was 30 removed under reduced pressure. To the resulting oil was added hexane (approx. 1L) and the mixture warmed to 60°C with swirling. After cooling to room temperature, the solids were collected and washed with 2L of hexane. The resulting solid was recrystallized from hot ethyl 35 acetate and hexane to afford 32.3g (43% yield) of N-benzyloxycarbonyl-3(S)-amino-1-chloro-4-phenyl-2(S)-butanol, mp 150-151°C and  $M+Li^+ = 340$ .

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Part B:

To a solution of 6.52g (0.116 mol, 1.2 equiv.) of potassium hydroxide in 968 mL of absolute ethanol at room temperature, was added 32.3g (0.097 mol) of N-CBZ-3(S)-amino-1-chloro-4-phenyl-2(S)-butanol. After stirring for fifteen minutes the solvent was removed under reduced pressure and the solids dissolved in methylene chloride. After washing with water, drying over magnesium sulfate, filtering and stripping, one obtains 27.9g of a white solid. Recrystallization from hot ethyl acetate and hexane afforded 22.3g (77% yield) of N-benzyloxycarbonyl-3(S)-amino-1,2(S)-epoxy-4-phenylbutane, mp 102-103°C and  $MH^+$  298.

15 Part C:

A solution of N-benzyloxycarbonyl 3(S)-amino-1,2-(S)-epoxy-4-phenylbutane (30.1g, 0.10 mol) and 165mL of isoamylamine in 150 mL of isopropyl alcohol was heated to reflux for 2.5 hours. The solution was cooled to room temperature, concentrated in vacuo and then recrystallized. The product was isolated by filtration and from ethyl acetate/hexane to afford 31.7g (81%) of N[3(S)-benzyloxycarbonylamino-2(R)-hydroxy-4-phenylbutyl]N-isoamylamine.

25 Part D:

A solution of N[3(S)-benzyloxycarbonylamino-2(R)-hydroxy-4-phenyl butyl], N-isoamylamine in 10 ml of tetrahydrofuran was treated with tert-butylisocyanate (267 mg, 2.70 mmol) at room temperature for 5 minutes. The solvent was removed in vacuo and replaced with ethyl acetate. The ethyl acetate solution was washed with 5% citric acid, water, and brine, dried over anhydrous  $MgSO_4$ , filtered and concentrated in vacuo to give 1.19g, 97% of N-benzyloxycarbonyl-3-[[[(1,1-dimethylethyl)amino]carbonyl](3-methylbutyl)amino]-2(R)-hydroxy-1(S)-(phenylmethyl)pyrrolamine,  $MH^+$  m/z = 470.

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Part E:

A solution of (37.3g, 77 mmol) of product from Part D in 100 mL of methanol was hydrogenated over 10% palladium-on-carbon for 4 hours to afford 26.1g of the desired product.

Example 35

Preparation of Butanediarnide, N-[3-[[[(1,1-dimethylethyl)amino]carbonyl](3-methylbutyl)amino]-2-hydroxy-1-(phenylmethyl)propyl]-, [1S-[1R\*, 2S\*]]-.

10 Part A:

To a solution of 102mg (0.29 mmol) of Example 34 Part E and 70 mg (0.89 mmol) of pyridine in 2 mL of methylene chloride was added 29 mg (0.29 mmol) of succinic anhydride. After 2 hours, ethyl acetate was added and then extracted with saturated NaHCO<sub>3</sub>. The aqueous layer was acidified, reextracted with ethyl acetate, washed with saturated brine, dried over magnesium sulfate, filtered and concentrated in vacuo to afford 78 mg (60%) of butanoic acid, 4-[[3-[[[(1,1-dimethylethyl)amino]carbonyl](3-methylbutyl)amino]-2-hydroxy-1-(phenylmethyl)propyl]amino]-4-oxo-, [1S-[1R\*, 2S\*]]-

Part B:

This was activated with EDC and N-hydroxybenzotriazole in N,N-dimethylformamide and then reacted with ammonia to generate the desired final compound.

Example 36Part A:

To a solution of 4.60g (24.7 mmol) of trans-diethyl 1,2-cyclopropanedicarboxylate in 100 mL of 50:50 v:v tetrahydrofuran/water was added 1.24g (29.6 mmol) of lithium hydroxide. After 17 hours, the tetrahydrofuran was removed in vacuo, the water layer washed with ethyl acetate, acidified with 1N hydrochloric acid and extracted with ethyl acetate. The organic layer was dried and stripped to afford 2.1g of crude product. After recrystallization from diethyl ether/hexane and

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then methylene chloride/hexane ne obtains 1.1g (28%) of trans-monoethyl 1,2-cyclopropanedicarboxylate,  $m/e = 159$  (M + H).

Part B:

- 5 To a solution of 297 mg (1.87 mmol) of trans-monoethyl 1,2-cyclopropanedicarboxylate and 429 mg (2.8 mmol) N-hydroxybenzotriazole (HOBT) in 3 mL of anhydrous N,N-dimethylformamide (DMF) at 0°C was added 394 mg (2.0 mmol) of 1-(3-dimethylaminopropyl)-3-ethylcarbodiimide hydrochloride (EDC). After 30 min. a solution of 591 mg (1.7 mmol) of product from Part A in 2 mL DMF and 171 mg (1.69 mmol) of N-methylmorpholine (NMM) was added. After 2 hours at 0°C, the reaction was stirred at RT overnight, poured into water, extracted with ethyl acetate, washed with water, 5% aq. citric acid, sat'd NaHCO<sub>3</sub>, brine, dried over anhydride MgSO<sub>4</sub> and stripped to afford 771 mg of crude product. This was chromatographed on silica gel using 5-20% methanol/methylene chloride to afford 670 mg (80%) of cyclopropane carboxylic acid, 2-[[[3-[[[(1,1-dimethylethyl)amino]carbonyl](3-methylbutyl)amino]-2-hydroxy-1-(phenylmethyl)propyl]amino]carbonyl]-, ethyl ester;  $m/e = 490$  (M + H).

Part C:

- 25 To a solution of 658 mg (1.32 mmol) of product from Part B in 5 mL of 50:50 THF/water was added 66 mg (1.58 mmol) of lithium hydroxide. After 19 hours, the THF was removed in vacuo, the water washed with ethyl acetate, acidified and reextracted with ethyl acetate. 30 The organic layer was dried and stripped to afford 328 mg (54%) of the corresponding acid,  $m/e = 462$  (M + H).

Part D:

- To a solution of 304 mg (0.66 mmol) of product from Part C, 151 mg (0.99 mmol) HOBT in 2.2 mL DMF at 35 0°C was added 139 mg (0.73 mmol) EDC. Aft r 30 min. at 0°C, 1.1 mL of conc. aque us ammonia was added. After stirring at 0°C for 2 hours and RT for 20 h urs, the reaction was p ured int brine and extract d with ethyl

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acetate. After washing with sat'd  $\text{NaHCO}_3$ , brine, drying and stripping, one obtains 141 mg of crude product. This was chromatographed on silica gel with 1-5% methanol/methylene chloride to afford 40 mg (13%) of the desired final product,  $m/e = 561$  ( $M + H$ ).

#### Example 37

Preparation of trans-but-2-enediamide, N-[3-[[[(1,1-dimethylethyl)amino]carbonyl](3-methylbutyl)amino]-2-hydroxy-1-(phenylmethyl)propyl]-, [1S-[1R\*, 2S\*]].

##### 10 Part A:

To a solution of 137 mg (0.95 mmol) fumaric acid monoethyl ester in 1 mL of DMF at  $0^\circ\text{C}$  was added 183 mg (0.95 mmol) EDCI. After 15 minutes, a solution of 333 mg (0.95 mmol) of the compound of Example 34 Part E in 1 mL DMF was added and the reaction stirred for 14 hours at RT. Ethyl acetate was added and extracted with sat'd brine, 0.2 N HCl, sat'd  $\text{NaHCO}_3$ , dried and stripped to afford 0.32g of crude product. Chromatography on silica gel using 0-50% ethyl acetate/hexane afforded 0.26g (58%) of but-2-enoic acid, 4-[[3-[[[(1,1-dimethylethyl)amino]carbonyl](3-methylbutyl)amino]-2-hydroxy-1-(phenylmethyl)propyl]amino]-4-oxo-, [1S-[1R\*, 2S\*]]-, ethyl ester,  $m/e = 476$  ( $M + H$ ).

##### Part B:

25 To a solution of 26.6 mg (0.56 mmol) of product from Part A in 3 mL of 50:50 THF/water was added 34 mg (0.82 mmol) of lithium hydroxide and the reaction stirred at RT for 1 hour. The THF was removed in vacuo, the aqueous layer acidified with 1N HCl and extracted with ethyl acetate. The organic layer was washed with brine, dried and stripped to afford 233 mg (93%) of trans-but-2-enoic acid, 4-[[3-[[[(1,1-dimethylethyl)amino]carbonyl](3-methylbutyl)amino]-2-hydroxy-1-(phenylmethyl)propyl]amino]-4-oxo-, [1S-[1R\*, 2S\*]]-,  $m/ = 448$  ( $M + H$ ).

##### Part C:

To a solution of 225 mg (0.50 mmol) of the product from Part B in 1 mL of DMF was added 95 mg (0.50

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mmol) EDC. After 15 minutes at RT, 0.50 mL of aqueous ammonia was added and the reaction stirred for 15 hours. Ethyl acetate was added and washed with 0.2N HCl, brine, dried and stripped to afford 170 mg of crude product. After chromatography on silica gel using 0-40% methanol/methylene chloride, one obtains 50 mg (22%) of trans-but-3-enediamide, N-[3-[[[(1,1-dimethylethyl)amino]carbonyl](3-methylbutyl)amino]-2-hydroxy-1-(phenylmethyl)propyl]-, [1S-[1R\*, 2S\*]-, m/e = 447 (M + H).

#### Example 38

Preparation of butanediamide, N-[3-[[[(1,1-dimethylethyl)amino]carbonyl](3-methylbutyl)amino]-2-hydroxy-1-(phenylmethyl)propyl-2-methyl-, [1S-[1R\*(2S\*)], 2S\*]-.

##### Part A:

To a suspension of 24.7g (0.22 mol) of itaconic anhydride in 100 mL of anhydrous toluene at reflux under a nitrogen atmosphere was added dropwise over 30 minutes 23.9g (0.22 mol) of benzyl alcohol. The insoluble material dissolved to provide a homogeneous solution which was refluxed for 1.5 hours. The solution was cooled to RT, then in an ice bath and the resulting white precipitate collected by filtration to afford 24.8g (51%) of 4-benzyl itaconate.

##### Part B:

To a solution of 2.13g (9.5 mmol) of the product from Part A in 12 mL of methylene chloride at 0°C was added 4.02g (29.1 mmol) of para-methoxybenzyl alcohol, 605 mg (4.95 mmol) of N,N-dimethyl 4-aminopyridine, 128 mg of N,N-dimethyl 4-aminopyridine hydrochloride salt and then 2.02g (4.7 mmol) dicyclohexylcarbodiimide (DCC). After stirring at 0°C for 1 hour and then RT for 2 hours, the precipitate was collected and discarded. The filtrate was washed with 0.5 N HCl, sat'd NaHCO<sub>3</sub>, dried and stripped to afford 4.76g of crude product. This was chromatographed on

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silica gel using 0-50% ethyl acetate/hexane to afford 1.24g of pure 4'-methoxybenzyl-4-benzylitaconate,  $MH^+$   $m/z$  = .

Part C:

5 A solution of 1.24g (3.65 mmol) of product from Part B and 20 mg of [(R,R)-Dipamp)cyclooctadienylrhodium] tetrafluoroborate in 30 mL of methanol was thoroughly degassed, flushed with nitrogen and then hydrogen and then stirred under 50  
10 psig of hydrogen for 15 hours. The solution was filtered and stripped, dissolved in methylene chloride and washed with sat'd  $NaHCO_3$ , dried and stripped to afford 0.99g of a brown oil. This was then dissolved in  
15 40 mL of methylene chloride, 3 mL of trifluoroacetic acid added and the solution stirred at RT for 3.5 hours. Water was added and separated and the organic layer extracted with sat'd  $NaHCO_3$ . The aqueous layer was acidified and reextracted with ethyl acetate, separated and the organic layer washed with brine, dried and  
20 stripped to afford 320 mg (50%) of 2(R)-methyl-4-benzylsuccinic acid.

Part D:

To a solution of 320 mg (1.44 mmol) of product from Part C and 314 mg (2.05 mmol) HOBT in DMF at 0°C  
25 was added 303 mg (1.58 mmol) of EDC. After stirring for 30 minutes, a solution of 467 mg (1.34 mmol) of the product from Example 34, Part E in 4 mL of DMF was added. After stirring for 1 hour at 0°C and 14 hours at RT, ethyl acetate was added and washed with sat'd  $NaHCO_3$ ,  
30 5% aqueous citric acid, dried and stripped to afford 0.97g of crude product. This was chromatographed on silica gel using 0-10% ethyl acetate/hexane to afford 420 mg of pure butanoic acid, 4-[[3-[[[(1,1-dimethylethyl)amino]carbonyl](3-methylbutyl)amino]-2-hydroxy-1-(phenylthio)pyrrolidinyl]amino]-3-methyl-4-oxo-,  
35 [1S-[1R\*(3S\*), 2S\*]-, benzyl ester.

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Part E:

A solution of 150 mg (0.27 mmol) of product from Part D in 15 mL of methanol was hydrogenated over 10% palladium on carbon under 50 psig hydrogen for 17 hours. The reaction was filtered and stripped to afford 125 mg (100%) of butanoic acid, 4-[[3-[[[(1,1-dimethylethyl)amino]carbonyl](3-methylbutyl)amino]-2-hydroxy-1-(phenylmethyl)propyl]amino]-3-methyl-4-oxo-, [1S-[1R\*(3S\*), 2S\*]-.

10 Part F:

To a solution of 125 mg (0.27 mmol) of product from Part E and 65 mg (0.42 mmol) of HOBT in 5 mL of DMF at 0°C was added 59 mg (0.31 mmol) of EDC. After 30 min. at 0°C, 1 mL of conc. aqueous ammonia was added. After stirring at 0°C for 2 hours and RT for 15 hours, ethyl acetate was added and washed with sat'd NaHCO<sub>3</sub>, 5% aqueous citric acid, dried and stripped to afford 90 mg of crude product. This was recrystallized from ethyl acetate/hexane to afford 40 mg (32%) of pure butanediamide, N-[3-[[[(1,1-dimethylethyl)amino]carbonyl](3-methylbutyl)amino]-2-hydroxy-1-(phenylmethyl)propyl]-2-methyl, [1S-[1R\*(2S\*), 2S\*]-.

Example 39

25 Preparation of butanediamide, N-[3-[[[(1,1-dimethylethyl)amino]carbonyl](3-methylbutyl)amino]-2-hydroxy-1-(phenylmethyl)propyl]-2-methyl, [1S-[1R\*(2R\*), 2S\*]-.

Part A:

30 A solution of 1.41g (4.1 mmol) of 4'-methoxybenzyl 4-benzylitaconate and 25 mg of [(S,S-Dipamp)cyclooctadienylrhodium]tetrafluoroborate in 20 mL of methanol was thoroughly degassed, flushed with nitrogen and then hydrogen and then stirred under 40 psig hydrogen for 72 hours. The solution was filtered and concentrated to provide 1.34g of a brown oil. This was dissolved in 40 mL of methylene chloride and 3 mL of trifluoroacetic acid was added. After stirring for 4



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hours, water was added, separated and the organic layer  
extracted with sat'd NaHCO<sub>3</sub>. The aqueous layer was  
separated, reacidified, extracted with ethyl acetate  
which was separated, washed with brine, dried and  
5 stripped to afford 440 mg of 2(S)-methyl-4-  
benzylsuccinic acid.

Part B:

To a solution of 440 mg (1.98 mmol) of the  
product from Part A and 437 mg (2.86 mmol) of HOBt in 9  
10 mL of DMF at 0°C was added 427 mg (2.23 mmol) of EDCI.  
After 30 minutes at 0°C, a solution of 653 mg (1.87  
mmol) of the product from Example 34, Part E in 3 mL DMF  
was added. After 1 hour at 0°C and 15 hours at RT,  
ethyl acetate was added, extracted with sat'd NaHCO<sub>3</sub>, 5%  
15 aqueous citric acid, dried and concentrated to afford  
0.98g of crude product. Chromatography on silica gel  
using 0-10% ethyl acetate afforded 610 mg (59%) of pure  
butanoic acid, 4-[[3-[[[(1,1-dimethylethyl)-  
amino]carbonyl](3-methylbutyl)amino]-2-hydroxy-1-  
20 (phenylmethyl)propyl]amino]-3-methyl-4-oxo-, [1S-  
[1R\*(3R\*), 2S\*], benzyl ester.

Part C:

A solution of 310 mg (0.56 mmol) of the  
product from Part B in 20 mL of methanol was  
25 hydrogenated over 20 mg of 10% palladium on carbon under  
50 psig hydrogen for 19 hours. The solution was  
filtered and concentrated to afford 220 mg (85%) of  
butanoic acid, 4-[[3-[[[(1,1-dimethylethyl)-  
amino]carbonyl](3-methylbutyl)amino]-2-hydroxy-1-  
30 (phenylmethyl)propyl]amino]-3-methyl-4-oxo-, [1S-  
[1R\*(3R\*), 2S\*].

Part D: To a solution of 190 mg (0.41 mmol) of the  
product from Part C and 90 mg (0.58 mmol) HOBt in 5 mL  
35 of DMF at 0°C, was added 88 mg (0.46 mmol) of EDCI.  
After 30 minutes at 0°C, 2 mL of conc. aqueous ammonia  
was added. After 1 hour at 0°C and 15 hours at RT,  
ethyl acetate was added, washed with sat'd NaHCO<sub>3</sub>, 5%

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aqueous citric acid, dried and concentrated to afford crude product. Recrystallization from ethyl acetate/hexane afforded 20 mg (11%) of butanediamide, N-[3-[[[(1,1-dimethylethyl)amino]carbonyl](3-methylbutyl)amino]-2-hydroxy-1-(phenylmethyl)propyl]-2-methyl, [1S-[1R\*(2R\*), 2S\*]]-.

#### Example 40

Preparation of butanediamide, N-[3-[[[(1,1-dimethylethyl)amino]carbonyl](3-methylbutyl)amino]-2-hydroxy-1-(phenylmethyl)propyl]-3-methyl-, [1S-[1R\*(3S\*), 2S\*]]-.

**Part A:** In a similar manner to the procedure used above, p-methoxybenzyl alcohol was reacted with itaconic anhydride in refluxing toluene to provide 4-(p-methoxybenzyl)itaconate.

**Part B:** To a solution of 3.30g (13.2 mmol) of the product from Part A in 17 mL of toluene, was added 2.08g (13.7 mmol) of 1,8-diazabicyclo[5.4.0]undec-7-ene and then 2.35g (13.7 mmol) of benzyl bromide. After 2 hours, the solution was filtered and the filtrate washed with sat'd NaHCO<sub>3</sub>, 3N HCl, brine, dried and concentrated to afford 3.12g of an oil. After chromatography on silica gel using 0-5% ethyl acetate/hexane one obtains 2.19g (49%) of benzyl 4-(4-methoxybenzyl)itaconate.

#### Part C:

A solution of 1.22g (3.6 mmol) of product from Part B and 150 mg of [(R,R-Dipamp)] cyclooctadienylrhodium] tetrafluoroborate in 15 mL of methanol was thoroughly degassed, flushed with nitrogen and then hydrogen and hydrogenated under 50 psig for 16 hours. The solution was filtered and concentrated to afford 1.2g of a brown oil. This was dissolved in 5 mL of methylene chloride and 5 mL of toluene and 3 mL of trifluoroacetic acid was added. After 4 hours, the solvents were removed in vacuo, the residue dissolved in methylene chloride, which was then extracted with sat'd

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NaHCO<sub>3</sub>. After separation, the aqueous layer was acidified, reextracted with methylene chloride which was then dried and concentrated to afford 470 mg (60%) of 3(R)-methyl-4-benzylsuccinic acid.

5 Part D:

To a solution of 470 mg (2.11 mmol) of product from Part C and 463 mg (3.03 mmol) of HOBT in 5 mL of DMF at 0°C was added 451 mg (2.35 mmol) of EDC. After 30 min. at 0°C, a solution of 728 mg (2.08 mmol) of the product from Example 34, Part E in 3 mL of DMF was added. After stirring at 0°C for 1 hour and 15 hours at RT, ethyl acetate was added and extracted with sat'd NaHCO<sub>3</sub>, 5% aqueous citric acid, brine, dried and concentrated to give 930 mg of crude product chromatography on silica gel using 0-10% ethyl acetate/hexane one obtains 570 mg (50%) of butanoic acid, 4-[[3-[[[(1,1-dimethylethyl)amino]carbonyl](3-methylbutyl)amino]-2-hydroxy-1-(phenylmethyl)propyl]amino]-2-methyl-4-oxo-, [1S-[1R\*(2S\*), 2S\*]-, benzyl ester.

Part E:

The product was hydrogenated in methanol using 10% palladium on carbon under 40 psig of hydrogen to afford butanoic acid, 4-[[3-[[[(1,1-dimethylethyl)amino]carbonyl](3-methylbutyl)amino]-2-hydroxy-1-(phenylmethyl)propyl]amino]-2-methyl-4-oxo-, [1S-[1R\*(2S\*), 2S\*]-.

Part F:

To a solution of 427 mg (0.92 mmol) of product from Part E and 210 mg (1.37 mmol) in 3 mL of DMF at 0°C was added 196 mg (1.02 mmol) of EDC. After 30 min. at 0°C, 2 mL of conc. aqueous ammonia was added. After 1 hour at 0°C and 15 hours at RT, ethyl acetate was added and then extracted with sat'd NaHCO<sub>3</sub>, brine, dried and concentrated to afford crude product. Recrystallization from ethyl acetate/hexane afforded 50 mg (12%) of butanediamide, N-[3-[[[(1,1-dimethylethyl)amino]carbonyl](3-methylbutyl)amino]-2-

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hydroxy-1-(phenylmethyl)propyl]-3-methyl-, [1S-  
[1R (3S\*), 2S\*]-.

Example 41

- 5 Preparation of butanediamide, N-[3-[[[(1,1-  
dimethylethyl)amino]carbonyl](3-methylbutyl)amino]-2-  
hydroxy-1-(phenylmethyl)propyl]-3-methyl-, [1S-  
[1R\*(3R\*), 2S\*]-.

This was prepared in an identical manner to  
10 the previous example except that the asymmetric  
hydrogenation step was done in the presence of [((S,S-  
dipamp)cyclooctadienyl)rhodium]-tetrafluoroborate as  
catalyst.

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Example 42

Preparation of butanediamide, N-[3-[[[(1,1-  
dimethylethyl)amino]carbonyl](3-methylbutyl)amino]-2-  
5 hydroxy-1-(phenylmethyl)propyl]-, [1S-[1R\*(2S\*, 3R\*),  
2S\*]] and [1S-[1R\*(2R\*, 3S\*), 2S\*]].

Part A:

To a solution of 863 mg (5.91 mmol) of meso-  
2,3-dimethylsuccinic acid in 7 mL of DMF at RT was added  
10 1.13g (5.91 mmol) of EDC. After 15 minutes, a solution  
of 2.07g (5.91 mmol) of the product from Example 34,  
Part E and 1.4 mL of pyridine in 7 mL of anhydrous  
methylene chloride was added. After 11 hours, ethyl  
acetate was added and washed with 0.2N HCl, brine, dried  
15 and concentrated to afford 2.73g (97%) of a 1:1 mixture  
of diastereomeric acids.

Part B:

To a solution of 1.45g (3.04 mmol) of the 1:1  
mixture from Part A and 613 mg (4.51 mmol) of HOBT in 10  
20 mL of DMF at 0°C was added 635 mg (3.31 mmol) of EDC.  
After 30 minutes at 0°C, 5 mL of conc. aqueous ammonia  
was added. After 1 hour at 0°C and 14 hours at RT,  
ethyl acetate was added, washed with 0.2N HCl, sat'd  
NaHCO<sub>3</sub>, brine, dried and concentrated to afford 0.64g  
25 (44%) of a 1:1 mixture of amides.

These were separated on a Whatman 10 micron  
partisil column using 8%-14% isopropanol/-methylene  
chloride. The first isomer to elute was identified as  
butanediamide, N-[3-[[[(1,1-  
30 dimethylethyl)amino]carbonyl](3-methylbutyl)amino]-2-  
hydroxy-1-(phenylmethyl)propyl]-, [1S-[1R\*(2R\*, 3S\*),  
2S\*], m/e/ = 477 (M + H).

The second isomer to elute was identified as  
butanediamide, N-[3-[[[(1,1-dimethylethyl)amino]-  
35 carbonyl](3-methylbutyl)amino]-2-hydroxy-1-  
(phenylmethyl)propyl]-, [1S-[1R\*(2S, 3R\*), 2S\*], m/e =  
477 (M + H).

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Example 43

Preparation of pentanediamide, N-[3-[[[(1,1-dimethylethyl)amino]carbonyl](3-methylbutyl)amino]-2-hydroxy-1-(phenylmethyl)propyl-3,3-dimethyl-, [1S-[1R\*, 2S\*]1.

Part A:

To a solution of 232 mg (0.66 mmol) of the product from Example 34, Part E and 98 mg (1.2 mmol) of pyridine in 2 mL of methylene chloride was added 95 mg (0.66 mmol) of 3,3-dimethylglutaric anhydride at RT. After 15 hours, ethyl acetate was added, washed with IN HCl, brine, dried and concentrated to afford 261 mg of crude product. Chromatography on silica gel using 5-20% methanol/methylene chloride afforded 108 mg of acid, m/e = 492 (M + H).

Part B:

To a solution of 92 mg (0.19 mmol) of product from Part A and 38 mg (0.28 mmol) HOBT in 0.5 mL DMF at 0°C was added 36 mg (0.19 mmol) of EDC. After 30 minutes at 0°C, 0.25 mL of conc. aqueous ammonia was added. After 1 hour at 0°C and 16 hours at RT, ethyl acetate was added, washed with 0.2N HCl, sat'd NaHCO<sub>3</sub>, brine, dried and concentrated to afford 72 mg of crude product. This was passed through a one-inch column of basic alumina with 10% methanol/methylene chloride to afford 53 mg of desired product, m/e = 491 (M + H).

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Example 44

Preparation of butanediamide, N-[3-[[[(1,1-dimethylethyl)amino]carbonyl](3-methylbutyl)amino]-2-hydroxy-1-(phenylmethyl)propyl]-2,3-dimethyl-[1S-[1R\*(2R\*, 3S\*), 2S\*]] (Isomer #1) and

Preparation of butanediamide, N-[3-[[[(1,1-dimethylethyl)amino]carbonyl](3-methylbutyl)amino]-2-hydroxy-1-(phenylmethyl)propyl]-2,3-dimethyl-[1S-[1R\*(2R\*, 3S\*), 2S\*]] (Isomer #2).

Part A:

To a solution of 1.47g (4.20 mmol) of the product from Example 34, Part E and 1.4 mL of pyridine in 9 mL of methylene chloride at RT was added 538 mg (4.20 mmol) of 2,2-dimethylsuccinic anhydride. After 15 hours, ethyl acetate was added and washed with 0.2N HCl, brine, dried and concentrated to afford 1.87g of crude product (approx. 3:1 mixture of isomers).

Part B:

To a solution of 1.85g (3.9 mmol) of crude product from Part A and 887 mg (5.8 mmol) of HOBT in 10 mL of DMF at 0°C was added 809 mg (4.2 mmol) EDC. After 30 minutes at 0°C, 6 mL of conc. aqueous ammonia was added. After 1 hour at 0°C and 15 hours at RT, ethyl acetate was added, washed with 0.2N HCl, sat'd NaHCO<sub>3</sub>, brine, dried and concentrated to afford 923 mg of crude product. The two isomers were separated on a Whatman Partisil 5 column using 8-14% isopropanol/methylene chloride. The major isomer was identified as Isomer #1, m/e = 477 (M + H).

The minor isomer was identified as Isomer #2, m/e = 477 (M + H).

Example 45

This example illustrates the procedure utilized to prepare compounds wherein the stereochemistry about the hydroxyl group is (S).

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Part A:

A solution of 3(S)-(1,1-dimethylethoxycarbonyl)amino-1,2-(R)-epoxy-4-phenylbutane (1.00g, 3.80 mmol) and isobutylamine (5.55g, 76 mmol, 20 equiv.) in 10 mL of isopropyl alcohol was warmed to 60°C for 1 hour. The solution was cooled to room temperature and concentrated in vacuo and the residue recrystallized from hexane/methylene chloride to give 0.93g, 73% of [2(S), 3(S)]-N-[[[3-[(1,1-dimethylethyl)carbamoyl]amino]]-2-hydroxy-4-phenylbutyl]N-[(3-methylbutyl)amine], mp 91.3 - 93.0°C.

Part B:

The product from Part A (46.3mg, 0.14 mmol) was dissolved in a mixture of 5 mL of tetrahydrofuran and 2 mL of methylene chloride and treated with tert-butylisocyanate (136.4mg, 1.376 mmol) via syringe. The solution was stirred at room temperature for 0.5 hour and then the solvent was removed in vacuo. The product, TLC on SiO<sub>2</sub>, 1:1 hexane: ethyl acetate had R<sub>f</sub> = 0.74 and was used directly in the next step without further purification.

Part C:

The crude product from Part B was taken up in 10 mL of 4N hydrochloric acid in dioxane and stirred at room temperature for 0.25 hours. The solvent and excess hydrochloric acid was removed in vacuo whereupon the product crystallized. The solid was isolated by filtration washed with acetone and dried in vacuo to 3-[[[(1,1-dimethylethyl)amino]carbonyl](2-methylpropyl)amino-2(S)-hydroxy-1(S)-(phenylmethyl)propylamine hydrochloride.

Part D:

A solution of N-Cbz-L-asparagine (225.5mg, 0.847 mmol) and N-hydroxybenzotriazole (192.9mg, 1.21 mmol) was dissolved in 2 mL of dimethylformamide and cooled to 0°C and then treated with EDC (170.2mg, 0.898 mmol) for 10 minutes. This mixture was then treated with 3-[[[(1,1-dimethylethyl)amino]carbonyl](2-



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5 methylpropyl)amin -2(S)-hydroxy-1(S)-  
(phenylmethyl)propylamine hydrochloride.  
(300.0mg, 0.807 mmol) followed by N-methylmorpholine  
(90.0mg, 0.888 mmol) via syringe. The solution was  
10 stirred at room temperature for 16 hours and then poured  
into 20 mL of rapidly stirring 60% saturated aqueous  
sodium bicarbonate solution whereupon a white  
precipitate formed. The solid was isolated by  
filtration, washed with saturated aqueous sodium  
15 bicarbonate solution, water, 5% aqueous citric acid  
solution, water and then dried in vacuo to give 319mg,  
68% of butanediamide, N<sup>1</sup>-[3-[[[(1,1-  
dimethylethyl)amino]carbonyl](2-methylpropyl)amino]-2(S)-  
hydroxy-1(S)-(phenylmethyl)propyl]-2(S)-  
20 [(benzyloxycarbonyl)amino] mp 139-141°C, MH<sup>+</sup> m/z = 584.

#### EXAMPLE 46

The compounds of the present invention are  
effective HIV protease inhibitors. Utilizing an enzyme  
assay as described below, the compounds set forth in the  
20 examples herein disclosed inhibited the HIV enzyme.  
The preferred compounds of the present invention and  
their calculated IC<sub>50</sub> (inhibiting concentration 50%,  
i.e., the concentration at which the inhibitor compound  
reduces enzyme activity by 50%) values are shown in  
25 Table 16. The enzyme method is described below. The  
substrate is 2-aminobenzoyl-Ile-Nle-Phe(p-NO<sub>2</sub>)-Gln-  
ArgNH<sub>2</sub>. The positive control is MVT-101 (Miller, M. et  
al, Science, 246, 1149 (1989)] The assay conditions are  
as follows:

30 Assay buffer: 20 mM sodium phosphate, pH 6.4  
20% glycerol  
1 mM EDTA  
1 mM DTT  
0.1% CHAPS

35 The above described substrate is dissolved in  
DMSO, then diluted 10 fold in assay buffer. Final  
substrate concentration in the assay is 80 μM.

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HIV protease is diluted in the assay buffer to a final enzyme concentration of 12.3 nanomolar, based on a molecular weight of 10,780.

5 The final concentration of DMSO is 14% and the final concentration of glycerol is 18%. The test compound is dissolved in DMSO and diluted in DMSO to 10x the test concentration; 10 $\mu$ l of the enzyme preparation is added, the materials mixed and then the mixture is incubated at ambient temperature for 15 minutes. The  
10 enzyme reaction is initiated by the addition of 40 $\mu$ l of substrate. The increase in fluorescence is monitored at 4 time points (0, 8, 16 and 24 minutes) at ambient temperature. Each assay is carried out in duplicate wells.

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TABLE 16

	Compound	IC <sub>50</sub> (nanomolar)
5	1a) Butanediamide, N <sup>1</sup> -[3-[[[(1,1-dimethylethyl)amino]carbonyl](2-methylpropyl)amino]-2-hydroxy-1-(phenylmethyl)propyl]-2-[(N-benzyl-oxycarbonyl)amino]-, [1S-[1R*(R*), 2S*]]-	35
10		
15	1b) Butanediamide, N <sup>1</sup> -[3-[[[(1,1-dimethylethyl)amino]carbonyl](2-methylpropyl)amino]-2-hydroxy-1-(phenylmethyl)propyl]-2-[(2-quinolinylcarbonyl)amino]-, [1S-[1R*(R*), 2S*]]-	7.1
20	2a) Butanediamide, N <sup>1</sup> -[3-[[[(1,1-dimethylethyl)amino]carbonyl](3-methylbutyl)amino]-2-hydroxy-1-(phenylmethyl)propyl]-2-[(N-benzyl-oxycarbonyl)amino]-, [1S-[1R*(R*), 2S*]]-	13.4
25		
30	2b) Butanediamide, N <sup>1</sup> -[3-[[[(1,1-dimethylethyl)amino]carbonyl](3-methylbutyl)amino]-2-hydroxy-1-(phenylmethyl)propyl]-2-[(2-quinolinylcarbonyl)amino]-, [1S-[1R*(R*), 2S*]]-	3.2
35	3a) Butanediamide, N <sup>1</sup> -[3-[[[(1,1-dimethylethyl)amino]carbonyl](2-naphthylmethyl)amino]-2-hydroxy-1-(phenylmethyl)propyl]-2-[(N-benzyl-oxycarbonyl)amino]-, [1S-[1R*(R*), 2S*]]-	31.0
40		
45	3b) Butanediamide, N <sup>1</sup> -[3-[[[(1,1-dimethylethyl)amino]carbonyl](2-naphthylmethyl)amino]-2-hydroxy-1-(phenylmethyl)propyl]-2-[(2-quinolinylcarbonyl)amino]-, [1S-[1R*(R*), 2S*]]-	2.9
50	4a) Butanediamide, N <sup>1</sup> -[3-[[[(1,1-dimethylethyl)amino]carbonyl](2-phenylethyl)amino]-2-hydroxy-1-(phenylmethyl)propyl]-2-[(N-benzyl-oxycarbonyl)amino]-, [1S-[1R*(R*), 2S*]]-	70

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TABLE 16 (C nt'd)

	Compound	IC <sub>50</sub> (nanomolar)
5		
10	4b) Butanediamide, N <sup>1</sup> -[3-[[[(1,1-dimethylethyl)amino]carbonyl](2-phenylethyl)amino]-2-hydroxy-1-(phenylmethyl)propyl]-2-[(2-quinolinylcarbonyl)amino]-, [1S-[1R*(R*),2S*]]-	10
15	5a) Butanediamide, N <sup>1</sup> -[3-[[[(1,1-dimethylethyl)amino]carbonyl](3,3-dimethylpropyl)amino]-2-hydroxy-1-(phenylmethyl)propyl]-2-[(N-benzoyloxycarbonyl)amino]-, [1S-[1R*(R*),2S*]]-	18
20	5b) Butanediamide, N <sup>1</sup> -[3-[[[(1,1-dimethylethyl)amino]carbonyl](3,3-dimethylpropyl)amino]-2-hydroxy-1-(phenylmethyl)propyl]-2-[(2-quinolinylcarbonyl)amino]-, [1S-[1R*(R*),2S*]]-	3.7
25		
30	6) Propanamide, N-[3-[[[(1,1-dimethylethyl)amino]carbonyl](3-methylbutyl)amino]-2-hydroxy-1-(phenylmethyl)propyl]-2-methyl-3-(methylsulfonyl)-, [1S-[1R*(R*),2S*]]-	29
35	7) Propanamide, 3-(acetylamino)-N-[3-[[[(1,1-dimethylethyl)amino]carbonyl](3-methylbutyl)amino]-2-hydroxy-1-(phenylmethyl)propyl]-2-methyl-, [1S-[1R*(S*),2S*]]-	100
40	8) Propanamide, 3-(4-methoxybenzyloxy-carbonyl)amino-N-[3-[[[(1,1-dimethylethyl)amino]carbonyl](3-methylbutyl)amino]-2-hydroxy-1-(phenylmethyl)propyl]-2-methyl-, [1S-[1R*(S*),2S*]]-	6
45		
50	9) Butanediamide, N <sup>1</sup> -[2-hydroxy-3-[(4-fluorophenylmethyl)(1-pyrrolidinyl-carbonyl)amino]-1-(phenylmethyl)propyl]-2-[(2-quinolinylcarbonyl)amino]-, [1S-[1R*(R*),2S*]]-	7
55	10) Butanediamide, N <sup>1</sup> -[3-[[[(1,1-dimethylethyl)amino]carbonyl](3-methylbutyl)amino]-2-hydroxy-1-(phenylmethyl)propyl]-2,3,3-trimethyl-, [1S-[1R*(2S*),2S*]]-	12

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TABLE 16 (C nt'd)

	Compound	IC <sub>50</sub> (nanomolar)
5		
10	11) Butanoic acid, 4-[[3-[[[(1,1-dimethylethyl)amino]carbonyl](3-methylbutyl)amino]-2-hydroxy-1-(phenylmethyl)propyl]amino-2,2,3-trimethyl-4-oxo-, [1S-[1R*(3S*), 2S*]]-	8
15	12) Butaneamide, 2-(acetylamino)-N-[3-[[[(1,1-dimethylethyl)amino]carbonyl](3-methylbutyl)amino]-2-hydroxy-1-(phenylmethyl)propyl]-3,3-dimethyl-, [1S-[1R*(R*), 2S*]]-	18

20

Example 47

The effectiveness of the compounds listed in Table 9 were determined in the above-described enzyme assay and in a CEM cell assay.

25 The HIV inhibition assay method of acutely infected cells is an automated tetrazolium based colorimetric assay essentially that reported by Pauwles et al, J. Virol. Methods 20, 309-321 (1988). Assays were performed in 96-well tissue culture plates. CEM

30 cells, a CD4<sup>+</sup> cell line, were grown in RPMI-1640 medium (Gibco) supplemented with a 10% fetal calf serum and were then treated with polybrene (2μg/ml). An 80 μl volume of medium containing 1 x 10<sup>6</sup> cells was dispensed into each well of the tissue culture plate. To each

35 well was added a 100μl volume of test compound dissolved in tissue culture medium (or medium without test compound as a control) to achieve the desired final concentration and the cells were incubated at 37°C for 1 hour. A frozen culture of HIV-1 was diluted in culture

40 medium to a concentration of 5 x 10<sup>6</sup> TCID<sub>50</sub> per ml (TCID<sub>50</sub> = the dose of virus that infects 50% of cells in tissue culture), and a 20μL volume of the virus sample (containing 1000 TCID<sub>50</sub> of virus) was added to wells containing test compound and to wells containing only

45 medium (infected control cells). Several wells received

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culture medium without virus (uninfected control cells). Likewise, the intrinsic toxicity of the test compound was determined by adding medium without virus to several wells containing test compound. In summary, the tissue culture plates contained the following experiments:

	Cells	Drug	Virus
1.	+	-	-
2.	+	+	-
3.	+	-	+
4.	+	+	+

In experiments 2 and 4 the final concentrations of test compounds were 1, 10, 100 and 500  $\mu\text{g/ml}$ . Either azidothymidine (AZT) or dideoxyinosine (ddI) was included as a positive drug control. Test compounds were dissolved in DMSO and diluted into tissue culture medium so that the final DMSO concentration did not exceed 1.5% in any case. DMSO was added to all control wells at an appropriate concentration.

Following the addition of virus, cells were incubated at 37°C in a humidified, 5%  $\text{CO}_2$  atmosphere for 7 days. Test compounds could be added on days 0, 2 and 5 if desired. On day 7, post-infection, the cells in each well were resuspended and a 100  $\mu\text{l}$  sample of each cell suspension was removed for assay. A 20  $\mu\text{L}$  volume of a 5 mg/ml solution of 3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyltetrazolium bromide (MTT) was added to each 100  $\mu\text{L}$  cell suspension, and the cells were incubated for 4 hours at 27°C in a 5%  $\text{CO}_2$  environment. During this incubation, MTT is metabolically reduced by living cells resulting in the production in the cell of a colored formazan product. To each sample was added 100  $\mu\text{l}$  of 10% sodium dodecylsulfate in 0.01 N HCl to lyse the cells, and samples were incubated overnight. The absorbance at 590 nm was determined for each sample using a Molecular Devices microplate reader. Absorbance values for each

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set of wells is compared to assess viral control infection, uninfected control cell response as well as test compound by cytotoxicity and antiviral efficacy.

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TABLE 17

	Compound	IC <sub>50</sub>	EC <sub>50</sub>	TD <sub>50</sub>
5	butanediamide N <sup>1</sup> [3-			
	[[[n-butylamino]carbonyl](2-			
	methylpropyl)amino]-2-hydroxy-			
10	1-(phenylmethyl)propyl]-2-			
	[(phenylmethylcarbonyl)			
	amino],[1S-[1R*(R*), 2S*]]--.	940nM	17μM	170- 180μM
15	butanediamide N <sup>1</sup> [3-			
	[[[n-butylamino]carbonyl](2-			
	methylpropyl)amino]-2-hydroxy-			
	1-(phenylmethyl)propyl]-2-			
	[(2-quinolinylcarbonyl)amino]-			
20	[1S-[1R*(R*), 2S*]]--.	126nM	26nM	53μM
	butanediamide N <sup>1</sup> [3-			
	[[[(1,1-dimethylethyl)amino]-			
	carbonyl](2-phenylethyl)amino]-			
25	2-hydroxy-1-(phenylmethyl)propyl]-			
	2-[(2-quinolinylcarbonyl)amino]			
	[1S-[1R*(R*), 2S*]]--.	10nM	28nM	13μM
	butanediamide N <sup>1</sup> [3-			
30	[[[(1,1-dimethylethyl)amino]-			
	carbonyl](2-methylpropyl)amino-			
	2-hydroxy-1-(phenylmethyl)propyl]-			
	2-[(2-quinolinylcarbonyl)amino]			
	[1S-[1R*(R*), 2S*]]--.	7nM	10nM	16μM
35				

Utilizing the procedures set forth above in the examples along with the general description, it is contemplated that the compounds listed below could be prepared and that such compounds would have activities



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as HIV proteas inhibit rs substantially similar to the activities of th comp unds set f rth in the examples.

- Butanediamide, N<sup>1</sup>-[3-[[[(1,1-  
 5 dimethylethyl)amino]carbonyl]pentylamino]-2-hydroxy-1-(phenylmethyl)propyl]-2-[(2-quinolinylcarbonyl)amino]-, [1S-[1R\*(R\*), 2S\*]]-
- Butanediamide, N<sup>1</sup>-[3-[[[(1,1-  
 10 dimethylethyl)amino]carbonyl]hexylamino]-2-hydroxy-1-(phenylmethyl)propyl]-2-[(2-quinolinylcarbonyl)amino]-, [1S-[1R\*(R\*), 2S\*]]-
- Propanamide, N-[3-[[[(1,1-  
 15 dimethylethyl)amino]carbonyl]butylamino]-2-hydroxy-1-(phenylmethyl)propyl]-2-methyl-3-(methylsulfonyl)-, [1S-[1R\*(R\*), 2S\*]]-
- Propanamide, N-[3-[[[(1,1-  
 20 dimethylethyl)amino]carbonyl](phenylmethyl)amino]-2-hydroxy-1-(phenylmethyl)propyl]-2-methyl-3-(methylsulfonyl)-, [1S-[1R\*(R\*), 2S\*]]-
- Propanamide, N-[3-[[[(1,1-  
 25 dimethylethyl)amino]carbonyl](4-fluorophenylmethyl)amino]-2-hydroxy-1-(phenylmethyl)propyl]-2-methyl-3-(methylsulfonyl)-, [1S-[1R\*(R\*), 2S\*]]-
- 30 Propanamide, N-[3-[[[(1,1-dimethylethyl)amino]carbonyl](4-methoxyphenylmethyl)amino]-2-hydroxy-1-(phenylmethyl)propyl]-2-methyl-3-(methylsulfonyl)-, [1S-[1R\*(R\*), 2S\*]]-
- 35 Propanamide, N-[3-[[[(1,1-dimethylethyl)amino]carbonyl](cyclohexylmethyl)amino]-

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2-hydroxy-1-(phenylmethyl)propyl]-2-methyl-3-(methylsulfonyl)-, [1S-[1R\*(R\*), 2S\*]]-

Propanamide, N-[3-[[[(1,1-dimethylethyl)amino]carbonyl](3-methylbutyl)amino]-2-hydroxy-1-(cyclohexylmethyl)propyl]-2-methyl-3-(methylsulfonyl)-, [1S-[1R\*(R\*), 2S\*]]-

Butanediamide, N<sup>1</sup>-[2-hydroxy-3-[(3-methylbutyl)(1-pyrrolidinylcarbonyl)amino]-1-(phenylmethyl)propyl]-2-[(2-quinolinylcarbonyl)amino]-, [1S-[1R\*(R\*), 2S\*]]-

Butanediamide, N<sup>1</sup>-[2-hydroxy-3-[(3-methylbutyl)(1-pyrrolidinylcarbonyl)amino]-1-(4-fluorophenylmethyl)propyl]-2-[(2-quinolinylcarbonyl)amino]-, [1S-[1R\*(R\*), 2S\*]]-

Butanediamide, N<sup>1</sup>-[2-hydroxy-3-[(3-methylbutyl)(1-pyrrolidinylcarbonyl)amino]-1-(cyclohexylmethyl)propyl]-2-[(2-quinolinylcarbonyl)amino]-, [1S-[1R\*(R\*), 2S\*]]-

Butanediamide, N<sup>1</sup>-[2-hydroxy-3-[(phenylmethyl)(4-morpholinylcarbonyl)amino]-1-(phenylmethyl)propyl]-2-[(2-quinolinylcarbonyl)amino]-, [1S-[1R\*(R\*), 2S\*]]-

Butanediamide, N<sup>1</sup>-[2-hydroxy-3-[(3-methylbutyl)(1-piperidinylcarbonyl)amino]-1-(phenylmethyl)propyl]-2-[(2-quinolinylcarbonyl)amino]-, [1S-[1R\*(R\*), 2S\*]]-

Butanediamide, N<sup>1</sup>-[2-hydroxy-3-[(phenylmethyl)(1-piperidinylcarbonyl)amino]-1-(phenylmethyl)propyl]-2-[(2-quinolinylcarbonyl)amino]-, [1S-[1R\*(R\*), 2S\*]]-

Butanediamide, N-[3-[[[(1,1-dimethylethyl)amino]carbonyl]butylamino]-2-hydroxy-1-(phenylmethyl)propyl]-2,3,3-trimethyl-, [1S-[1R\*(2S\*), 2S\*]]-

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Butanediamid , N-[3-[[[(1,1-  
dim thylethyl)amino]carb nyl](phenylmethyl)amino]-2-  
hydroxy-1-(phenylmethyl)propyl]-2,3,3-trimethyl-, [1S-  
[1R\*(2S\*),2S\*]]-

5

Butanediamide, N-[3-[[[(1,1-  
dimethylethyl)amino]carbonyl](4-  
fluorophenylmethyl)amino]-2-hydroxy-1-  
(phenylmethyl)propyl]-2,3,3-trimethyl-, [1S-  
[1R\*(2S\*),2S\*]]-

10

Butanediamide, N-[3-[[[(1,1-  
dimethylethyl)amino]carbonyl](cyclohexylmethyl)amino]-  
2-hydroxy-1-(phenylmethyl)propyl]-2,3,3-trimethyl-, [1S-  
[1R\*(2S\*),2S\*]]-

15

Butanediamide, N-[3-[[[(1,1-  
dimethylethyl)amino]carbonyl](3-methylbutyl)amino]-2-  
hydroxy-1-(cyclohexylmethyl)propyl]-2,3,3-trimethyl-,  
[1S-[1R\*(2S\*),2S\*]]-

20

Butanoic acid, 4-[3-[[[(1,1-  
dimethylethyl)amino]carbonyl]butylamino]-2-hydroxy-1-  
(phenylmethyl)propyl]amino-2,2,3-trimethyl-4-oxo-, [1S-  
[1R\*(3S\*),2S\*]]-

25

Butanoic acid, 4-[3-[[[(1,1-  
dimethylethyl)amino]carbonyl](phenylmethyl)amino]-2-  
hydroxy-1-(phenylmethyl)propyl]amino-2,2,3-trimethyl-4-  
oxo-, [1S-[1R\*(3S\*),2S\*]]-

30

Butanoic acid, 4-[3-[[[(1,1-  
dimethylethyl)amino]carbonyl](4-  
fluorophenylmethyl)amino]-2-hydroxy-1-  
(phenylmethyl)propyl]amino-2,2,3-trimethyl-4-oxo-, [1S-  
[1R\*(3S\*),2S\*]]-

35

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Butan ic acid, 4-[[3-[[[(1,1-dimethylethyl)amino]carbonyl](cyclohexylmethyl)amino]-2-hydroxy-1-(phenylmethyl)propyl]amino-2,2,3-trimethyl-4-oxo-, [1S-[1R\*(3S\*),2S\*]]-

5

Butaneamide,  
2-(acetyl amino)-N-[3-[[[(1,1-dimethylethyl)amino]carbonyl](3-methylbutyl)amino]-2-hydroxy-1-(cyclohexylmethyl)propyl]-3,3-dimethyl-, [1S-[1R\*(R\*),2S\*]]-

10

Butaneamide,  
2-(acetyl amino)-N-[3-[[[(1,1-dimethylethyl)amino]carbonyl]butylamino]-2-hydroxy-1-(phenylmethyl)propyl]-3,3-dimethyl-, [1S-[1R\*(R\*),2S\*]]-

15

Butaneamide,  
2-(acetyl amino)-N-[3-[[[(1,1-dimethylethyl)amino]carbonyl](phenylmethyl)amino]-2-hydroxy-1-(phenylmethyl)propyl]-3,3-dimethyl-, [1S-[1R\*(R\*),2S\*]]-

20

Butaneamide,  
2-(acetyl amino)-N-[3-[[[(1,1-dimethylethyl)amino]carbonyl](cyclohexylmethyl)amino]-2-hydroxy-1-(phenylmethyl)propyl]-3,3-dimethyl-, [1S-[1R\*(R\*),2S\*]]-

25

Butaneamide,  
2-[(2,2-dimethylaminoacetyl)amino]-N-[3-[[[(1,1-dimethylethyl)amino]carbonyl](3-methylbutyl)amino]-2-hydroxy-1-(4-fluorophenylmethyl)propyl]-3,3-dimethyl-, [1S-[1R\*(R\*),2S\*]]-

30

Butaneamide,  
2-[(2,2-dimethylaminoacetyl)amino]-N-[3-[[[(1,1-dimethylthyl)amino]carbonyl](3-methylbutyl)amino]-2-

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hydroxy-1-(cyclohexylmethyl)propyl]-3,3-dimethyl-, [1S-[1R\*(R\*),2S\*]]-

Butaneamide,

5 2-[(2,2-dimethylaminoacetyl)amino]-N-[3-[[[(1,1-dimethylethyl)amino]carbonyl]butylamino]-2-hydroxy-1-(phenylmethyl)propyl]-3,3-dimethyl-, [1S-[1R\*(R\*),2S\*]]-

10 Butaneamide,

2-[(2,2-dimethylaminoacetyl)amino]-N-[3-[[[(1,1-dimethylethyl)amino]carbonyl](phenylmethyl)amino]-2-hydroxy-1-(phenylmethyl)propyl]-3,3-dimethyl-, [1S-[1R\*(R\*),2S\*]]-

15

Butaneamide,

2-[(2,2-dimethylaminoacetyl)amino]-N-[3-[[[(1,1-dimethylethyl)amino]carbonyl](4-fluorophenylmethyl)amino]-2-hydroxy-1-

20 (phenylmethyl)propyl]-3,3-dimethyl-, [1S-[1R\*(R\*),2S\*]]-

Butaneamide,

25 2-[(2,2-dimethylaminoacetyl)amino]-N-[3-[[[(1,1-dimethylethyl)amino]carbonyl](cyclohexylmethyl)amino]-2-hydroxy-1-(phenylmethyl)propyl]-3,3-dimethyl-, [1S-[1R\*(R\*),2S\*]]-

30 The compounds of the present invention are effective antiviral compounds and, in particular, are effective retroviral inhibitors as shown above. Thus, the subject compounds are effective HIV protease inhibitors. It is contemplated that the subject compounds will also inhibit other viruses such as HIV,  
35 human T-cell leukemia virus, respiratory syncytial virus, hepatitis virus, cytomegal virus and parvovirus.

The compounds of the present invention can be used in the form of salts derived from inorganic or

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organic acids. These salts include but are not limited to the following: acetate, adipate, alginate, citrate, aspartate, benzoate, benzenesulfonate, bisulfate, butyrate, camphorate, camphorsulfonate, digluconate, 5 cyclopentanepropionate, dodecylsulfate, ethanesulfonate, glucoheptanoate, glycerophosphate, hemisulfate, heptanoate, hexanoate, fumarate, hydrochloride, hydrobromide, hydroiodide, 2-hydroxy-ethanesulfonate, lactate, maleate, methanesulfonate, nicotinate, 2- 10 naphthalenesulfonate, oxalate, palmoate, pectinate, persulfate, 3-phenylpropionate, picrate, pivalate, propionate, succinate, tartrate, thiocyanate, tosylate, mesylate and undecanoate. Also, the basic nitrogen-containing groups can be quaternized with such agents as 15 lower alkyl halides, such as methyl, ethyl, propyl, and butyl chloride, bromides, and iodides; dialkyl sulfates like dimethyl, diethyl, dibutyl, and diamyl sulfates, long chain halides such as decyl, lauryl, myristyl and stearyl chlorides, bromides and iodides, aralkyl halides 20 like benzyl and phenethyl bromides, and others. Water or oil-soluble or dispersible products are thereby obtained.

Examples of acids which may be employed to form pharmaceutically acceptable acid addition salts 25 include such inorganic acids as hydrochloric acid, sulphuric acid and phosphoric acid and such organic acids as oxalic acid, maleic acid, succinic acid and citric acid. Other examples include salts with alkali metals or alkaline earth metals, such as sodium, 30 potassium, calcium or magnesium or with organic bases.

Total daily dose administered to a host in single or divided doses may be in amounts, for example, from 0.001 to 10 mg/kg body weight daily and more 35 usually 0.01 to 1 mg. Dosage unit compositions may contain such amounts of submultiples thereof to make up the daily dose.

The amount of active ingredient that may be combined with the carrier materials to produce a single

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dosage form will vary depending upon the host treated and the particular mode of administration.

It will be understood, however, that the specific dose level for any particular patient will  
5 depend upon a variety of factors including the activity of the specific compound employed, the age, body weight, general health, sex, diet, time of administration, route of administration, rate of excretion, drug combination, and the severity of the particular disease undergoing  
10 therapy.

The compounds of the present invention may be administered orally, parenterally, by inhalation spray, rectally, or topically in dosage unit formulations containing conventional nontoxic pharmaceutically  
15 acceptable carriers, adjuvants, and vehicles as desired. Topical administration may also involve the use of transdermal administration such as transdermal patches or iontophoresis devices. The term parenteral as used herein includes subcutaneous injections, intravenous,  
20 intramuscular, intrasternal injection, or infusion techniques.

Injectable preparations, for example, sterile injectable aqueous or oleaginous suspensions may be formulated according to the known art using suitable  
25 dispersing or wetting agents and suspending agents. The sterile injectable preparation may also be a sterile injectable solution or suspension in a nontoxic parenterally acceptable diluent or solvent, for example, as a solution in 1,3-butanediol. Among the acceptable  
30 vehicles and solvents that may be employed are water, Ringer's solution, and isotonic sodium chloride solution. In addition, sterile, fixed oils are conventionally employed as a solvent or suspending medium. For this purpose any bland fixed oil may be  
35 employed including synthetic mono- or diglycerides. In addition, fatty acids such as oleic acid find use in the preparation of injectables.

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Suppositories for rectal administration of the drug can be prepared by mixing the drug with a suitable nonirritating excipient such as cocoa butter and polyethylene glycols which are solid at ordinary temperatures but liquid at the rectal temperature and will therefore melt in the rectum and release the drug.

Solid dosage forms for oral administration may include capsules, tablets, pills, powders, and granules. In such solid dosage forms, the active compound may be admixed with at least one inert diluent such as sucrose lactose or starch. Such dosage forms may also comprise, as in normal practice, additional substances other than inert diluents, e.g., lubricating agents such as magnesium stearate. In the case of capsules, tablets, and pills, the dosage forms may also comprise buffering agents. Tablets and pills can additionally be prepared with enteric coatings.

Liquid dosage forms for oral administration may include pharmaceutically acceptable emulsions, solutions, suspensions, syrups, and elixirs containing inert diluents commonly used in the art, such as water. Such compositions may also comprise adjuvants, such as wetting agents, emulsifying and suspending agents, and sweetening, flavoring, and perfuming agents.

While the compounds of the invention can be administered as the sole active pharmaceutical agent, they can also be used in combination with one or more immunomodulators, antiviral agents or other antiinfective agents. When administered as a combination, the therapeutic agents can be formulated as separate compositions which are given at the same time or different times, or the therapeutic agents can be given as a single composition.

The foregoing is merely illustrative of the invention and is not intended to limit the invention to the disclosed compounds. Variations and changes which are obvious to one skilled in the art are intended to be



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within the scope and nature of the invention which are defined in the appended claims.

The preceding examples can be repeated with similar success by substituting the generically or  
5 specifically described reactants and/or operating conditions of this invention for those used in the preceding examples.

From the foregoing description, one skilled in the art can easily ascertain the essential  
10 characteristics of this invention, and without departing from the spirit and scope thereof, can make various changes and modifications of the invention to adapt it to various usages and conditions.

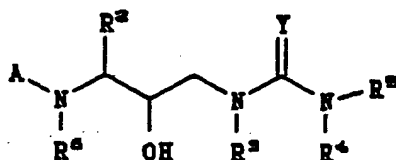
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WHAT IS CLAIMED IS:

1. A compound represented by the formula:

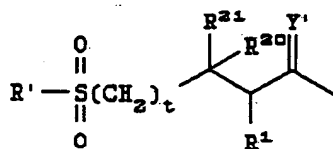
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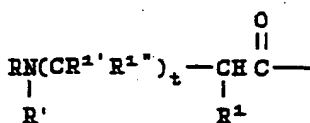


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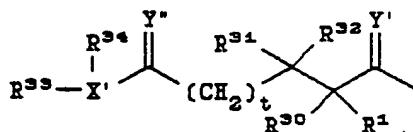
wherein A represents radicals represented by formulas:



(A1)



(A2)



(A3)

wherein

- 20 R represents hydrogen and alkoxycarbonyl, aralkoxycarbonyl, alkylcarbonyl, cycloalkylcarbonyl, cycloalkylalkoxycarbonyl, cycloalkylalkanoyl,

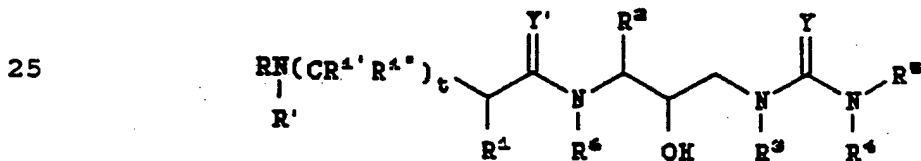
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- alkanoyl, aralkanoyl, aroyl, aryloxycarbonyl,  
aryloxyalkanoyl, heterocyclylcarbonyl,  
heterocyclyloxycarbonyl, heterocyclylalkanoyl,  
heterocyclylalkoxycarbonyl, heteroaralkoxycarbonyl,  
5 heteroaryloxycarbonyl, heteroaroyl, alkyl, aryl,  
aralkyl, aryloxyalkyl, heteroaryloxyalkyl,  
hydroxyalkyl, alkylaminocarbonyl, arylaminocarbonyl,  
aralkylaminoalkylcarbonyl, aminoalkanoyl radicals,  
alkylaminoalkylcarbonyl and mono- and disubstituted  
10 aminoalkanoyl radicals wherein the substituents are  
selected from alkyl, aryl, aralkyl, cycloalkyl,  
cycloalkylalkyl, heteroaryl, heteroaralkyl,  
heteroalkyl, heterocycloalkylalkyl radicals;
- R' represents hydrogen and radicals as defined for R<sup>3</sup> or  
15 R and R' together with the nitrogen to which they are  
attached form a heterocycloalkyl or heteroaryl radical;  
t represents 0 or 1;
- R<sup>1</sup> represents -CH<sub>2</sub>SO<sub>2</sub>NH<sub>2</sub>, hydrogen, CO<sub>2</sub>CH<sub>3</sub>, CONH<sub>2</sub>, alkyl  
and cycloalkyl radicals and amino acid side chains  
20 selected from asparagine, S-methyl cysteine and the  
corresponding sulfoxide and sulfone derivatives  
thereof, glycine, glutamine, allo-isoleucine,  
leucine, tert-leucine, phenylalanine, ornithine,  
alanine, isoleucine, histidine, norleucine, valine,  
25 threonine, allo-threonine, serine, aspartic acid and  
beta-cyano alanine side chains;
- R<sup>1'</sup> and R<sup>1''</sup> independently represent hydrogen and radicals  
as defined for R<sup>1</sup>;
- R<sup>2</sup> represents alkyl, aryl, cycloalkyl, cycloalkylalkyl  
30 and aralkyl radicals optionally substituted with a  
group selected from -NO<sub>2</sub>, -OR<sup>9</sup>, -SR<sup>9</sup>, and halogen  
radicals, wherein R<sup>9</sup> represents hydrogen and alkyl  
radicals;
- R<sup>3</sup> represents alkyl, alkenyl, hydroxyalkyl, cycloalkyl,  
35 cycl alkylalkyl, heterocycloalkyl,  
heterocycl alkylalkyl, aryl, aralkyl, and  
heter aralkyl radicals;

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- X' represents O, N and C(R<sup>17</sup>) wherein R<sup>17</sup> represents hydrogen and alkyl radicals;
- Y, Y' and Y'' independently represent O and S;
- R<sup>4</sup> and R<sup>5</sup> independently represent hydrogen and radicals as defined by R<sup>3</sup>, or R<sup>4</sup> and R<sup>5</sup> together with the nitrogen atom to which they are bonded represent heterocycloalkyl and heteroaryl radicals;
- R<sup>6</sup> represents hydrogen and radicals as defined for R<sup>3</sup>;
- R<sup>20</sup>, R<sup>21</sup>, R<sup>30</sup>, R<sup>31</sup> and R<sup>32</sup> represent radicals as defined for R<sup>1</sup>, or one of R<sup>1</sup> and R<sup>30</sup> together with one of R<sup>31</sup> and R<sup>32</sup> and the carbon atoms to which they are attached form a cycloalkyl radical; or R<sup>30</sup> and R<sup>32</sup> together with the carbon atoms to which they are attached form a three to six-membered cycloalkyl radical; and
- R<sup>33</sup> and R<sup>34</sup> independently represent hydrogen and radicals as defined for R<sup>3</sup>, or R<sup>33</sup> and R<sup>34</sup> together with X' represent cycloalkyl, aryl, heterocyclyl and heteroaryl radicals, provided that when X' is O, R<sup>34</sup> is absent.

2. Compound represented by the formula:



30

wherein;

- R represents alkoxycarbonyl, aralkoxycarbonyl, alkylcarbonyl, cycloalkylcarbonyl, cycloalkylalkoxycarbonyl, cycloalkylalkanoyl, alkanoyl, cycloalkanoyl, cycloalkylalkanoyl, aralkanoyl, aroyl, aryloxycarbonyl, aryloxyalkanoyl, heterocyclocarbonyl, heterocyclyloxycarbonyl, heterocyclyl, alkanoyl, heterocyclylalkoxycarbonyl, heteroaralkoxycarbonyl, heteroaryloxycarbonyl, heteroaroyl alkyl, aryl, aralkyl, aryloxyalkyl, heteroaryloxyalkyl, hydroxyalkyl, alkylamin carbonyl,

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- arylaminoacarbonyl, aralkylamin alkylcarbonyl, and aminoalkan yl radicals; alkylaminoalkylcarbonyl and mono- and disubstituted aminoalkanoyl radicals wherein the substituents are selected from alkyl, aryl, aralkyl, cycloalkyl, cycloalkylalkyl, heteroaryl, heteroaralkyl, heteroalkyl, heterocycloalkylalkyl radicals;
- 5        R' represents hydrogen and radicals as defined for R<sup>3</sup>, or R and R' together with the nitrogen to which they are attached form a heterocycloalkyl or heteroaryl radical;
- 10        R<sup>1</sup> represents -CH<sub>2</sub>SO<sub>2</sub>NH<sub>2</sub>, hydrogen, CO<sub>2</sub>CH<sub>3</sub>, CONH<sub>2</sub>, alkyl and cycloalkyl radicals, and amino acid side chains selected from the group of asparagine, S-methyl cysteine and the sulfoxide (SO) and sulfone (SO<sub>2</sub>) derivatives thereof, histidine, norleucine, glutamine, glycine, allo-isoleucine, alanine, threonine, isoleucine, leucine, text-leucine, phenylalanine, ornithine, allo-threonine, serine, aspartic acid, beta-cyano alanine and valine side chains;
- 15        R<sup>1'</sup> and R<sup>1''</sup> independently represent hydrogen and radicals as defined for R<sup>1</sup>;
- 20        R<sup>2</sup> represents alkyl, aryl, cycloalkyl, cycloalkylalkyl, and aralkyl radicals, which radicals are optionally substituted with a group selected from halogen radicals and NO<sub>2</sub>, -OR<sup>9</sup> and SR<sup>9</sup> wherein R<sup>9</sup> represents hydrogen and alkyl radicals;
- 25        R<sup>3</sup> represents alkyl, alkenyl, hydroxyalkyl, cycloalkyl, cycloalkylalkyl, heterocycloalkyl, heterocycloalkylalkyl, aryl, aralkyl, heteroaryl and heteroaralkyl radicals;
- 30        R<sup>4</sup> and R<sup>5</sup> independently represent hydrogen and radicals as defined by R<sup>3</sup>, or together with the nitrogen atom t which they are bonded represent pyrrolidinyl, piperidinyl, morpholinyl and piperazinyl radicals;
- 35        t represents O or 1; and
- Y and Y' independently represent O and S.

3. Compound of Claim 2 wherein R represents aralkoxycarbonyl and heteroaroyl radicals.

4. Compound of Claim 2 wherein R represents carbobenzoy, 2-benzofurancarbonyl and 2-

5 quinolinylcarbonyl radicals.

5. Compound of Claim 2 wherein R represents carbobenzoy.

6. Compound of Claim 2 wherein R represents 2-quinolinylcarbonyl and 2-benzofurancarbonyl radicals.

10 7. Compound of Claim 2 wherein R<sup>1</sup> represents alkyl radicals and amino acid side chains selected from the group consisting of asparagine, valine, threonine, allo-threonine, isoleucine, S-methyl cysteine and the sulfone and sulfoxide derivatives thereof, alanine, and  
15 allo-isoleucine.

8. Compound of Claim 2 wherein R<sup>1</sup> represents methyl, t-butyl, isopropyl and sec-butyl radicals, and amino acid side chains selected from the group consisting of asparagine, valine, S-methyl cysteine,  
20 allo-iso-leucine, iso-leucine, threonine, srine, aspartic acid, beta-cyano alanine, and allo-threonine side chains.

9. Compound of Claim 2 wherein R<sup>1</sup> represents methyl and t-butyl radicals.

25 10. Compound of Claim 2 wherein R<sup>1</sup> represents a t-butyl radical when t is 0.

11. Compound of Claim 2 wherein R<sup>1</sup> represents amino acid side chains selected from asparagine, valine, alanine and isoleucine side chains.

30 12. Compound of Claim 2 wherein R<sup>1</sup> represents amino acid side chains selected from asparagine, iso-leucine and valine side chains.

13. Compound of Claim 2 wherein R<sup>1</sup> represents an asparagine side chain.

35 14. Compound of Claim 2 wherein R<sup>1</sup> represents a t-butyl radical and an asparagine side chain.

15. Compound of Claim 2 wherein R<sup>1</sup> represents a m thyl radical when t is 1.

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16. Compound of Claim 2 wherein t is 0.
17. Compound of Claim 2 wherein t is 1.
18. Compound of Claim 2 wherein R<sup>2</sup> represents alkyl, cycloalkylalkyl and aralkyl radicals, which  
5 radicals are optionally substituted with halogen radicals and radicals represented by the formula -OR<sup>9</sup> and -SR<sup>9</sup> wherein R<sup>9</sup> represents alkyl radicals.
19. Compound of Claim 2 wherein R<sup>2</sup> represents alkyl, cycloalkylalkyl and aralkyl radicals.
- 10 20. Compound of Claim 2 wherein R<sup>2</sup> represents aralkyl radicals.
21. Compound of Claim 2 wherein R<sup>2</sup> represents CH<sub>3</sub>SCH<sub>2</sub>CH<sub>2</sub>-, iso-butyl, n-butyl, benzyl, 4-fluorobenzyl, 2-naphthylmethyl and cyclohexylmethyl radicals.
- 15 22. Compound of Claim 2 wherein R<sup>2</sup> represents an n-butyl and iso-butyl radicals.
23. Compound of Claim 2 wherein R<sup>2</sup> represents benzyl, 4-fluorobenzyl and 2-naphthylmethyl radicals.
24. Compound of Claim 2 wherein R<sup>2</sup> represents  
20 a cyclohexylmethyl radical.
25. Compound of Claim 2 wherein R<sup>3</sup>, R<sup>4</sup> and R<sup>5</sup> independently represent alkyl, alkenyl, hydroxyalkyl, cycloalkyl, cycloalkylalkyl, heterocycloalkyl, heterocycloalkylalkyl, aryl, aralkyl and heteroaralkyl  
25 radicals.
26. Compound of Claim 25 wherein R<sup>5</sup> represents hydrogen.
27. Compound of Claim 25 wherein R<sup>3</sup> and R<sup>4</sup> independently represent alkyl and alkenyl radicals.
- 30 28. Compound of Claim 26 wherein R<sup>3</sup> and R<sup>4</sup> independently represent alkyl and hydroxyalkyl radicals.
29. Compound of Claim 26 wherein R<sup>3</sup> and R<sup>4</sup> independently represent alkyl, cycloalkyl and cycloalkylalkyl radicals.
- 35 30. Compound of Claim 26 wherein R<sup>3</sup> and R<sup>4</sup> independently represent alkyl, heterocycloalkyl and heterocycloalkylalkyl radicals.

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31. Compound of Claim 26 wherein  $R^3$  and  $R^4$  independently represent alkyl, aryl and aralkyl radicals.
32. Compound of Claim 26 wherein  $R^4$  represents  
5 a t-butyl, ethyl, isopropyl and 1,1-dimethylpropyl radicals.
33. Compound of Claim 2 wherein  $R^3$  represents alkyl radicals having from about 2 to about 5 carbon atoms.
- 10 34. Compound of Claim 2 wherein  $R^3$  represents n-pentyl, n-hexyl, n-propyl, i-butyl, neo-pentyl, i-amyl, and n-butyl radicals.
35. Compound of Claim 2 wherein  $R^3$ ,  $R^4$  and  $R^5$  independently represent alkyl radicals having from about  
15 2 to about 5 carbon atoms, cycloalkylalkyl radicals, aralkyl radicals, heterocycloalkylalkyl radicals and heteroaralkyl radicals.
36. Compound of Claim 2 wherein  $R^3$  represents benzyl, para-fluorobenzyl, para-methoxybenzyl, para-  
20 methylbenzyl, and 2-naphthylmethyl radicals and  $R^4$  represents t-butyl.
37. Compound of Claim 2 wherein  $R^3$  is cyclohexylmethyl and  $R^4$  is t-butyl.
38. Compound of Claim 2 wherein  $R^3$  is i-amyl  
25 and  $R^4$  is t-butyl.
39. Compound of Claim 2 wherein  $R^3$  is i-butyl and  $R^4$  is t-butyl.
40. Compound of Claim 2 wherein  $R^3$  is n-butyl and  $R^4$  is t-butyl.
- 30 41. Compound of Claim 2 wherein  $R^3$  is neo-pentyl and  $R^4$  is t-butyl.
42. Compound of Claim 2 wherein  $R^4$  represents alkyl and cycloalkyl radicals.
43. Compound of Claim 2 wherein  $R^5$  represents  
35 hydrogen and alkyl and cycloalkyl radicals.
44. Compound of Claim 2 wherein  $R^4$  and  $R^5$  together with the nitrogen to which they are bonded



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r present pyrrolidinyl, piperidinyl, morpholinyl, and piperazinyl radicals.

45. Compound of Claim 2 wherein R<sup>3</sup> represents heteroaralkyl radicals and R<sup>4</sup> is t-butyl.

5 46. Compound of Claim 2 wherein R<sup>3</sup> is a p-fluorobenzyl radical and R<sup>4</sup> is a t-butyl radical.

47. Compound of Claim 2 wherein R<sup>3</sup> is a 4-pyridylmethyl radical or its N-oxide and R<sup>4</sup> is a t-butyl radical.

10 48. Compound of Claim 2 wherein R<sup>4</sup> and R<sup>5</sup> together with the nitrogen atom to which they are attached represent a 5 or 6-membered heterocyclyl radical.

15 49. Compound of Claim 2 wherein R<sup>4</sup> and R<sup>5</sup> together with the nitrogen atom to which they are attached represent a 5 or 6-membered heterocyclyl radical substituted with an alkyl radical having from 1 to about 3 carbon atoms.

20 50. Compound of Claim 2 wherein R<sup>1</sup> and R<sup>1'</sup> are both hydrogen and R<sup>1''</sup> represents an alkyl radical having from 1 to about 4 carbon atoms.

51. Compound of Claim 2 wherein R<sup>1</sup> and R<sup>1'</sup> are both hydrogen and R<sup>1''</sup> represents -CH<sub>2</sub>SO<sub>2</sub>NH<sub>2</sub>, CO<sub>2</sub>NH<sub>2</sub>, CO<sub>2</sub>CH<sub>3</sub>, alkyl and cycloalkyl radicals and amino acid side chains selected from asparagine, S-methyl cysteine and the sulfone and sulfoxide derivatives thereof, histidine, norleucine, glutamine, glycine, allo-isoleucine, alanine, threonine, isoleucine, leucine, tert-leucine, phenylalanine, ornithine, allo-threonine, 25 serine, aspartic acid, beta-cyano alanine and valine side chains.

52. Compound of Claim 2 where t is O and R<sup>1</sup> represents the amino acid side chain of asparagine.

35 53. Compound of Claim 52 where R represents a heteroaroyl radical.

54. Compound of Claim 52 where R represents a 2-quinolinylcarbonyl or 2-benz furancarboxyl radical.

55. Compound of Claim 2 where t is 0 and R<sup>1</sup> represents a t-butyl radical or an amino acid side chain of valine or isoleucine.

56. Compound of Claim 55 where R represents an arylalkanoyl, aryloxycarbonyl, alkanoyl, mono-substituted aminoalkanoyl, or disubstituted aminoalkanoyl, or mono- or dialkylaminocarbonyl radical.

57. Compound of Claim 55 where R represents an arylalkanoyl, aryloxycarbonyl or alkanoyl radical.

58. Compound of Claim 55 where R represents a monosubstituted aminoalkanoyl or disubstituted aminoalkanoyl radical.

59. Compound of Claim 55 where R represents acetyl, N,N-dimethylaminoacetyl or N-benzyl-N-methylaminoacetyl.

60. Compound of Claim 2 where t is 1 and R<sup>1</sup> is a methyl radical.

61. Compound of Claim 60 where R represents an alkanoyl, arylalkanoyl, aryloxyalkanoyl or arylalkyloxycarbonyl radical.

62. Compound of Claim 60 where R represents a phenoxyacetyl, 2-naphthyloxyacetyl, benzyloxycarbonyl or p-methoxybenzyloxycarbonyl radical.

63. Compound of Claim 2 wherein t is 1, R<sup>1</sup> and R<sup>1'</sup> are both hydrogen and R<sup>1''</sup> is CONH<sub>2</sub>.

64. Compound of Claim 60 where R represents an alkylaminocarbonyl radical.

65. Compound of Claim 60 where R represents an N-methylaminocarbonyl radical.

66. A pharmaceutical composition comprising a compound of Claim 1 and a pharmaceutically acceptable carrier.

67. A pharmaceutical composition comprising a compound of Claim 2 and a pharmaceutically acceptable carrier.

68. Method of inhibiting a retroviral protease comprising administering a protease inhibiting amount of a composition of Claim 66.

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69. Method of Claim 68 wherein the retroviral protease is HIV protease.

70. Method of treating a retroviral infection comprising administering an effective amount of a composition of Claim 66.

71. Method of Claim 70 wherein the retroviral infection is an HIV infection.

72. Method for treating AIDS comprising administering an effective amount of a composition of Claim 66.

73. Method of inhibiting a retroviral protease comprising administering a protease inhibiting amount of a composition of Claim 67.

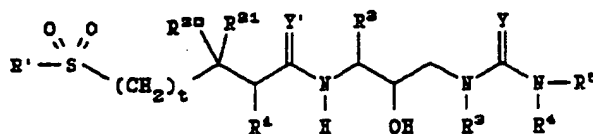
74. Method of Claim 73 wherein the retroviral protease is HIV protease.

75. Method of treating a retroviral infection comprising administering an effective amount of a composition of Claim 67.

76. Method of Claim 75 wherein the retroviral infection is an HIV infection.

77. Method for treating AIDS comprising administering an effective amount of a composition of Claim 67.

78. Compound represented by the formula:



wherein

R<sup>1</sup> represents radicals as defined for R<sup>3</sup>;

R<sup>1</sup> represents -CH<sub>2</sub>SO<sub>2</sub>NH<sub>2</sub>, alkyl and cycloalkyl radicals and amino acid side chains selected from asparagine, S-methyl cysteine and the corresponding sulfoxide and sulfone derivatives thereof, glycine, isoleucine, alanine, leucine, tert-leucine,

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phenylalanine, ornithine, threonine, all -threonine, is leucine, histidine, norleucine, valine, serine, aspartic acid, beta-cyano side chains;

5  $R^2$  represents alkyl, aryl, cycloalkyl, cycloalkylalkyl and aralkyl radicals optionally substituted with a group selected from  $-OR^9$ ,  $-SR^9$ , and halogen radicals, wherein  $R^9$  represents hydrogen and alkyl radicals;

$R^3$  represents alkyl, alkenyl, hydroxyalkyl, cycloalkyl, cycloalkylalkyl, heterocycloalkyl, 10 heterocycloalkylalkyl, aryl, heteroaryl, aralkyl, and heteroaralkyl radicals;

$R^4$  and  $R^5$ , independently represent hydrogen and radicals as defined by  $R^3$ , or  $R^4$  and  $R^5$  together with the nitrogen atom to which they are bonded represent 15 heterocycloalkyl and heteroaryl radicals;

$R^{20}$  and  $R^{21}$  represent radicals as defined for  $R^1$ ; and Y and Y' independently represent O and S.

79. Compound of Claim 78 wherein t is O.

80. Compound of Claim 78 wherein  $R^1$  represents 20 hydrogen and alkyl radicals.

81. Compound of Claim 78 wherein  $R^1$  represents alkyl radicals having from 1 to about 4 carbon atoms.

82. Compound of Claim 78 wherein  $R^1$  represents methyl, ethyl, isopropyl and t-butyl radicals.

25 83. Compound of Claim 78 wherein  $R^{20}$  and  $R^{21}$  independently represent hydrogen and alkyl radicals.

84. Compound of Claim 78 wherein  $R^{20}$  and  $R^{21}$  independently represent hydrogen and methyl radicals.

30 85. Compound of Claim 78 wherein  $R^{20}$  is hydrogen and  $R^{21}$  is an alkyl radical.

86. Compound of Claim 78 wherein  $R^1$  represents alkyl, aryl and aralkyl radicals.

87. Compound of Claim 78 wherein  $R^1$  is selected from methyl and phenethyl radicals.

35 88. Compound of Claim 78 wherein  $R^2$  represents alkyl, cycloalkylalkyl and aralkyl radicals, which radicals are optionally substituted with halogen

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radicals and radicals represented by the formula  $-OR^9$  and  $-SR^9$  wherein  $R^9$  represents alkyl radicals.

89. Compound of Claim 78 wherein  $R^2$  represents alkyl, cycloalkylalkyl and aralkyl radicals.

5 90. Compound of Claim 78 wherein  $R^2$  represents aralkyl radicals.

91. Compound of Claim 78 wherein  $R^2$  represents  $CH_3SCH_2CH_2-$ , iso-butyl, n-butyl, benzyl, 4-fluorobenzyl, 2-naphthylmethyl and cyclohexylmethyl radicals.

10 92. Compound of Claim 78 wherein  $R^2$  represents an n-butyl and iso-butyl radicals.

93. Compound of Claim 78 wherein  $R^2$  represents benzyl, 4-fluorobenzyl, and 2-naphthylmethyl radicals.

15 94. Compound of Claim 78 wherein  $R^2$  represents a cyclohexylmethyl radical.

95. Compound of Claim 78 wherein  $R^3$ ,  $R^4$  and  $R^5$  independently represent alkyl, alkenyl, hydroxyalkyl, cycloalkyl, cycloalkylalkyl, heterocycloalkyl, heterocycloalkylalkyl, aryl, aralkyl and heteroaralkyl radicals.

20 96. Compound of Claim 95 wherein  $R^5$  represents hydrogen.

97. Compound of Claim 95 wherein  $R^3$  and  $R^4$  independently represent alkyl and alkenyl radicals.

25 98. Compound of Claim 96 wherein  $R^3$  and  $R^4$  independently represent alkyl and hydroxyalkyl radicals.

99. Compound of Claim 96 wherein  $R^3$  and  $R^4$  independently represent alkyl, cycloalkyl and cycloalkylalkyl radicals.

30 100. Compound of Claim 96 wherein  $R^3$  and  $R^4$  independently represent alkyl, heterocycloalkyl and heterocycloalkylalkyl radicals.

101. Compound of Claim 96 wherein  $R^3$  and  $R^4$  independently represent alkyl, aryl and aralkyl radicals.

35 102. Compound of Claim 96 wherein  $R^3$  and  $R^4$  independently represent alkyl, cycloalkyl, cycloalkylalkyl, heterocycloalkyl,

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heterocycloalkylalkyl, aryl, aralkyl, and heteroaralkyl radicals.

103. Compound of Claim 78 wherein  $R^3$  represents alkyl radicals having from about 2 to about 5 carbon atoms.

104. Compound of Claim 96 wherein  $R^4$  represents ethyl, i-propyl, t-butyl and 1,1-dimethylpropyl radicals.

105. Compound of Claim 78 wherein  $R^3$ ,  $R^4$  and  $R^5$  independently represent alkyl radicals having from about 2 to about 5 carbon atoms, cycloalkylalkyl radicals, aralkyl radicals, heterocycloalkylalkyl radicals and heteroaralkyl radicals.

106. Compound of Claim 78 wherein  $R^3$  represents benzyl, para-fluorobenzyl, para-methoxybenzyl, para-methylbenzyl, and 2-naphthylmethyl radicals and  $R^4$  represents t-butyl.

107. Compound of Claim 78 wherein  $R^3$  is cyclohexylmethyl and  $R^4$  is t-butyl.

108. Compound of Claim 78 wherein  $R^3$  is i-amyl and  $R^4$  is t-butyl.

109. Compound of Claim 78 wherein  $R^3$  is i-butyl and  $R^4$  is t-butyl.

110. Compound of Claim 78 wherein  $R^3$  is n-butyl and  $R^4$  is t-butyl.

111. Compound of Claim 78 wherein  $R^3$  is neopentyl and  $R^4$  is t-butyl.

112. Compound of Claim 78 wherein  $R^4$  represents alkyl and cycloalkyl radicals.

113. Compound of Claim 78 wherein  $R^5$  represents hydrogen and alkyl and cycloalkyl radicals.

114. Compound of Claim 78 wherein  $R^4$  and  $R^5$  together with the nitrogen to which they are bonded represent pyrrolidinyl, piperidinyl, morpholinyl, and piperazinyl radicals.

115. Compound of Claim 78 wherein  $R^3$  represents heteroaralkyl radicals and  $R^4$  is t-butyl.

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116. Comp und of Claim 78 wherein  $R^3$  is a p-fluor benzyl radical and  $R^4$  is a t-butyl radical.

117. A pharmaceutical composition comprising a compound of Claim 78 and a pharmaceutically acceptable  
5 carrier.

118. Method of inhibiting a retroviral protease comprising administering a protease inhibiting amount of a composition of Claim 117.

119. Method of Claim 118 wherein the  
10 retroviral protease is HIV protease.

120. Method of treating a retroviral infection comprising administering an effective amount of a composition of Claim 117.

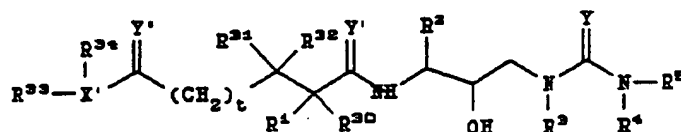
121. Method of Claim 120 wherein the  
15 retroviral infection is an HIV infection.

122. Method for treating AIDS comprising administering an effective amount of a composition of Claim 117.

123. Compound represented by the formula:

20

25



30

wherein:

$R^1$  represents  $-\text{CH}_2\text{SO}_2\text{NH}_2$ , alkyl and cycloalkyl radicals and amino acid side chains selected from the group  
35 consisting of asparagine, S-methyl cysteine and the corresponding sulfoxide and sulfone derivatives thereof, glycine, allo-isoleucine, alanine, leucine, tert-leucine, phenylalanine, ornithine, threonine, allo-threonine, isoleucine, histidine, norleucine,  
40 valin , glutamine, serine, aspartic acid and beta-cyan alanine side chains;

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- $R^2$  represents alkyl, aryl, cycl alkyl, cycloalkylalkyl and aralkyl radicals opti nally substituted with a group selected from  $-OR^9$ ,  $-SR^9$ , and halogen radicals, wherein  $R^9$  represents hydrogen and alkyl radicals;
- $R^3$  represents alkyl, alkenyl, hydroxyalkyl, cycloalkyl, cycloalkylalkyl, heterocycloalkyl, heterocycloalkylalkyl, aryl, heteroaryl, aralkyl, and heteroaralkyl radicals;
- $R^4$  and  $R^5$ , independently represent hydrogen and radicals as defined by  $R^3$ , or  $R^4$  and  $R^5$ , together with the nitrogen atom to which they are bonded represent heterocycloalkyl and heteroaryl radicals;
- $R^{30}$ ,  $R^{31}$  and  $R^{32}$  represent radicals as defined for  $R^1$ , or one of  $R^1$  and  $R^{30}$  together with one of  $R^{31}$  and  $R^{32}$  and the carbon atoms to which they are attached form a cycloalkyl radical; or  $R^{30}$  and  $R^{32}$  together with the carbon atoms to which they are attached form a three to six-membered cycloalkyl radical;
- $R^{33}$  and  $R^{34}$  independently represent hydrogen and radicals as defined for  $R^3$ , or  $R^{33}$  and  $R^{34}$  together with  $X'$  represent cycloalkyl, aryl, heterocyclyl and heteroaryl radicals, provided that when  $X'$  is O,  $R^{34}$  is absent.
- $X'$  represents N, O or  $C(R^{17})$  wherein  $R^{17}$  represents hydrogen and alkyl radicals.
- $Y$ ,  $Y'$  and  $Y''$  independently represent O and S;
124. Compound of Claim 123 wherein  $Y$ ,  $Y'$  and  $Y''$  are O.
125. Compound of Claim 123 wherein  $t$  is O.
126. Compound of Claim 123 wherein  $X'$  represents N.
127. Compound of Claim 126 wherein  $R^1$  represents hydrogen and alkyl radicals having from 1 to about 4 carbon atoms, aralkyl radicals, hydr xyl radicals, and radicals repr sented by the f rmula -  $CH_2C(O)R''$  wherein  $R''$  represents  $R^{38}$ ,  $-NR^{38}R^{39}$  and  $R^{38}-OR$



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wherein  $R^{38}$  and  $R^{39}$  independently represent hydrogen and alkyl radicals having from 1 to about 4 carbon atoms.

128. Compound of Claim 123 wherein  $R^1$  represents hydrogen, methyl, ethyl, benzyl, phenylpropyl, hydroxyl and radicals represented by the formula

$-CH_2C(O)R''$  wherein  $R''$  represents  $-CH_3$ ,  $NH_2$  and  $-OH$ .

129. Compound of Claim 125 wherein  $R^1$  and  $R^{31}$  are both hydrogen and  $R^{30}$  and  $R^{32}$  are both methyl.

130. Compound of Claim 125 wherein  $R^{30}$  is hydrogen and  $R^1$ ,  $R^{31}$  and  $R^{32}$  are all methyl.

131. Compound of Claim 125 wherein  $R^{30}$ ,  $R^{31}$  and  $R^{32}$  are hydrogen and  $R^1$  is methyl.

132. Compound of Claim 125 wherein  $R^1$  and  $R^{31}$  are both hydrogen and  $R^{30}$  and  $R^{32}$  together with the carbon atoms to which they are attached form a three to six-membered cycloalkyl radical.

133. Compound of Claim 125 wherein  $X'$  is O and  $R^{33}$  is hydrogen or an alkyl radical.

134. Compound of Claim 125 wherein  $X'$  is O,  $R^{34}$  is absent and  $R^{33}$  represents an aralkyl radical.

135. Compound of Claim 125 wherein  $R^2$  represents alkyl, cycloalkylalkyl and aralkyl radicals, which radicals are optionally substituted with halogen radicals and radicals represented by the formula  $-OR^9$  and  $-SR^9$  wherein  $R^9$  represents alkyl radicals.

136. Compound of Claim 125 wherein  $R^2$  represents alkyl, cycloalkylalkyl and aralkyl radicals.

137. Compound of Claim 125 wherein  $R^2$  represents aralkyl radicals.

138. Compound of Claim 125 wherein  $R^2$  represents  $CH_3SCH_2CH_2-$ , iso-butyl, n-butyl, benzyl, 2-naphthylmethyl and cyclohexylmethyl radicals.

139. Compound of Claim 125 wherein  $R^2$  represents an n-butyl and iso-butyl radicals.

140. Compound of Claim 125 wherein  $R^2$  represents benzyl, 4-fluorobenzyl, and 2-naphthylmethyl radicals.

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141. Compound of Claim 125 wherein R<sup>2</sup> represents a cyclohexylmethyl radical.

142. Compound of Claim 125 wherein R<sup>3</sup>, R<sup>4</sup> and R<sup>5</sup> independently represent alkyl, alkenyl, hydroxyalkyl, cycloalkyl, cycloalkylalkyl, heterocycloalkyl, heterocycloalkylalkyl, aryl, aralkyl and heteroaralkyl radicals.

143. Compound of Claim 125 wherein R<sup>5</sup> represents hydrogen.

144. Compound of Claim 142 wherein R<sup>3</sup> and R<sup>4</sup> independently represent alkyl and alkenyl radicals.

145. Compound of Claim 143 wherein R<sup>3</sup> and R<sup>4</sup> independently represent alkyl and hydroxyalkyl radicals.

146. Compound of Claim 143 wherein R<sup>3</sup> and R<sup>4</sup> independently represent alkyl, cycloalkyl and cycloalkylalkyl radicals.

147. Compound of Claim 143 wherein R<sup>3</sup> and R<sup>4</sup> independently represent alkyl, heterocycloalkyl and heterocycloalkylalkyl radicals.

148. Compound of Claim 143 wherein R<sup>3</sup> and R<sup>4</sup> independently represent alkyl, aryl and aralkyl radicals.

149. Compound of Claim 143 wherein R<sup>3</sup> and R<sup>4</sup> independently represent alkyl, cycloalkyl, cycloalkylalkyl, heterocycloalkyl, heterocycloalkylalkyl, aryl, aralkyl, and heteroaralkyl radicals.

150. Compound of Claim 125 wherein R<sup>3</sup> represents alkyl radicals having from about 2 to about 5 carbon atoms.

151. Compound of Claim 125 wherein R<sup>3</sup> independently represent n-propyl, i-butyl, neo-pentyl, n-pentyl, n-hexyl, i-amyl, and n-butyl radicals.

152. Compound of Claim 125 wherein R<sup>3</sup>, R<sup>4</sup> and R<sup>5</sup> independently represent alkyl radicals having from about 2 to about 5 carbon atoms, cycloalkylalkyl radicals, aralkyl radicals, heterocycloalkylalkyl radicals and heteroaralkyl radicals.

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153. Compound of Claim 125 wherein  $R^3$  represents benzyl, para-fluorobenzyl, para-methoxybenzyl, para-methylbenzyl, and 2-naphthylmethyl radicals and  $R^4$  represents t-butyl.

5 154. Compound of Claim 125 wherein  $R^3$  is cyclohexylmethyl and  $R^4$  is t-butyl.

155. Compound of Claim 125 wherein  $R^3$  is isopentyl or n-butyl and  $R^4$  is t-butyl.

10 156. Compound of Claim 125 wherein  $R^3$  is isobutyl and  $R^4$  is t-butyl.

157. Compound of Claim 125 wherein  $R^3$  is benzyl or p-fluorobenzyl and  $R^4$  is t-butyl.

158. Compound of Claim 125 wherein  $R^3$  is neopentyl and  $R^4$  is t-butyl.

15 159. Compound of Claim 125 wherein  $R^4$  represents alkyl and cycloalkyl radicals.

160. Compound of Claim 125 wherein  $R^4$  represents ethyl, i-propyl, t-butyl and 1,1-dimethylpropyl radicals.

20 161. Compound of Claim 125 wherein  $R^4$  and  $R^5$  together with the nitrogen to which they are bonded represent pyrrolidinyl, piperidinyl, morpholinyl, and piperazinyl radicals.

25 162. Compound of Claim 125 wherein  $R^3$  represents heteroaralkyl radicals and  $R^4$  is t-butyl.

163. Compound of Claim 125 wherein  $R^3$  is a p-fluorobenzyl radical and  $R^4$  is a t-butyl radical.

30 164. A pharmaceutical composition comprising a compound of Claim 123 and a pharmaceutically acceptable carrier.

165. Method of inhibiting a retroviral protease comprising administering a protease inhibiting amount of a composition of Claim 164.

35 166. Method of Claim 165 wherein the retroviral protease is HIV protease.

167. Method of treating a retroviral infection comprising administering an effective amount of a composition of Claim 164.

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168. Method of Claim 167 wherein the retroviral infection is an HIV infection.

169. Method for treating AIDS comprising administering an effective amount of a composition of  
5 Claim 164.

170. A compound of Claim 1 which is:  
Butanediamide, N<sup>1</sup>-[3-[[[(1,1-  
dimethylethyl)amino]carbonyl](2-methylpropyl)amino]-2-  
hydroxy-1-(phenylmethyl)propyl]-2-[(2-  
10 quinolinylcarbonyl)amino]-, [1S-[1R\*(R\*),2S\*]]-;

Butanediamide, N<sup>1</sup>-[3-[[[(1,1-  
dimethylethyl)amino]carbonyl]propylamino]-2-hydroxy-1-  
(phenylmethyl)propyl]-2-[(2-quinolinylcarbonyl)amino]-,  
15 [1S-[1R\*(R\*),2S\*]]-;

Butanediamide, N<sup>1</sup>-[3-[[[(1,1-  
dimethylethyl)amino]carbonyl]butylamino]-2-hydroxy-1-  
(phenylmethyl)propyl]-2-[(2-quinolinylcarbonyl)amino]-,  
20 [1S-[1R\*(R\*),2S\*]]-;

Butanediamide, N<sup>1</sup>-[3-[[[(1,1-  
dimethylethyl)amino]carbonyl](phenylmethyl)amino]-2-  
hydroxy-1-(phenylmethyl)propyl]-2-[(2-  
25 quinolinylcarbonyl)amino]-, [1S-[1R\*(R\*),2S\*]]-;

Butanediamide, N<sup>1</sup>-[3-[[[(1,1-  
dimethylethyl)amino]carbonyl](4-  
fluorophenylmethyl)amino]-2-hydroxy-1-  
30 (phenylmethyl)propyl]-2-[(2-quinolinylcarbonyl)amino]-,  
[1S-[1R\*(R\*),2S\*]]-;

Butanediamide, N<sup>1</sup>-[3-[[[(1,1-  
dimethylethyl)amino]carbonyl](4-  
methoxyphenylmethyl)amino]-2-hydroxy-1-  
35 (phenylmethyl)propyl]-2-[(2-quinolinylcarbonyl)amino]-,  
[1S-[1R\*(R\*),2S\*]]-;

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Butanediamide, N<sup>1</sup>-[3-[[[(1,1-dimethyl thyl)amino]carbonyl](3-methylbutyl)amin]-2-hydroxy-1-(phenylmethyl)propyl]-2-[(2-quinolinylcarbonyl)amino]-, [1S-[1R\*(R\*),2S\*]]-;

5

Butanediamide, N<sup>1</sup>-[3-[[[(1,1-dimethylethyl)amino]carbonyl](3,3-dimethylpropyl)amino]-2-hydroxy-1-(phenylmethyl)propyl]-2-[(2-quinolinylcarbonyl)amino]-, [1S-[1R\*(R\*),2S\*]]-;

10

Butanediamide, N<sup>1</sup>-[3-[[[(1,1-dimethylethyl)amino]carbonyl](4-hydroxybutyl)amino]-2-hydroxy-1-(phenylmethyl)propyl]-2-[(2-quinolinylcarbonyl)amino]-, [1S-[1R\*(R\*),2S\*]]-;

15

Butanediamide, N<sup>1</sup>-[3-[[[(1,1-dimethylethyl)amino]carbonyl](4-pyridylmethyl)amino]-2-hydroxy-1-(phenylmethyl)propyl]-2-[(2-quinolinylcarbonyl)amino]-, [1S-[1R\*(R\*),2S\*]]-;

20

Butanediamide, N<sup>1</sup>-[3-[[[(1,1-dimethylethyl)amino]carbonyl](2-phenylethyl)amino]-2-hydroxy-1-(phenylmethyl)propyl]-2-[(2-quinolinylcarbonyl)amino]-, [1S-[1R\*(R\*),2S\*]]-;

25

Butanediamide, N<sup>1</sup>-[3-[[[(1,1-dimethylethyl)amino]carbonyl](2-naphthylmethyl)amino]-2-hydroxy-1-(phenylmethyl)propyl]-2-[(2-quinolinylcarbonyl)amino]-, [1S-[1R\*(R\*),2S\*]]-;

30

Butanediamide, N<sup>1</sup>-[3-[[[(1,1-dimethylethyl)amino]carbonyl](cyclohexylmethyl)amino]-2-hydroxy-1-(phenylmethyl)propyl]-2-[(2-quinolinylcarbonyl)amino]-, [1S-[1R\*(R\*),2S\*]]-;

35

Butanediamide, N<sup>1</sup>-[3-[[[(1,1-dimethylethyl)amin]carbonyl](3-methylbutyl)amin]-2-

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hydroxy-1-(4-fluorophenylmethyl)propyl]-2-[(2-quinolinylnylcarbonyl)amino]-, [1S-[1R\*(R\*),2S\*]]-;

5 Butanediamide, N<sup>1</sup>-[3-[[[(1,1-dimethylethyl)amino]carbonyl](3-methylbutyl)amino]-2-hydroxy-1-(cyclohexylmethyl)propyl]-2-[(2-quinolinylnylcarbonyl)amino]-, [1S-[1R\*(R\*),2S\*]]-;

10 Butanediamide, N<sup>1</sup>-[3-[[[(1,1-dimethylethyl)amino]carbonyl](3-methylbutyl)amino]-2-hydroxy-1-(butyl)propyl]-2-[(2-quinolinylnylcarbonyl)amino]-, [1S-[1R\*(R\*),2S\*]]-;

15 Propanamide, N-[3-[[[(1,1-dimethylethyl)amino]carbonyl](3-methylbutyl)amino]-2-hydroxy-1-(phenylmethyl)propyl]-2-methyl-3-(methylsulfonyl)-, [1S-[1R\*(R\*), 2S\*]]-;

20 Propanamide, N-[3-[[[(1,1-dimethylethyl)amino]carbonyl](3-methylbutyl)amino]-2-hydroxy-1-(4-fluorophenylmethyl)propyl]-2-methyl-3-(methylsulfonyl)-, [1S-[1R\*(R\*), 2S\*]]-;

25 Propanamide, 3-(acetylamino)-N-[3-[[[(1,1-dimethylethyl)amino]carbonyl](3-methylbutyl)amino]-2-hydroxy-1-(phenylmethyl)propyl]-2-methyl-, [1S-[1R\*(S\*),2S\*]]-;

30 Propanamide, 3-(acetylamino)-N-[3-[[[(1,1-dimethylethyl)amino]carbonyl](3-methylbutyl)amino]-2-hydroxy-1-(4-fluorophenylmethyl)propyl]-2-methyl-, [1S-[1R\*(S\*),2S\*]]-;

35 Propanamide, 3-(acetylamino)-N-[3-[[[(1,1-dimethylethyl)amino]carbonyl](3-methylbutyl)amin]-2-hydroxy-1-(cyclohexylmethyl)propyl]-2-methyl-, [1S-[1R\*(S),2S\*]]-;

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- Propanamid , 3-(phen xyacetyl amino)-N-[3-[[[(11,-  
dimethyl thyl)amin ]carbonyl](3-methylbutyl)amin ]-2-  
hydroxy-1-(phenylmethyl)propyl]-2-methyl-, [1S-  
[1R\*(S\*),2S\*]]-;
- 5 Propanamide, 3-(2-naphthyloxyacetyl amino)-N-[3-[[[(11,-  
dimethylethyl) amino]carbonyl](3-methylbutyl) amino]-2-  
hydroxy-1-(phenylmethyl)propyl]-2-methyl-, [1S-  
[1R\*(S\*),2S\*]]-;
- 10 Propanamide, 3-(4-methoxybenzyloxycarbonyl) amino-N-[3-  
[[[(11,-dimethylethyl) amino]carbonyl](3-methyl-  
butyl) amino]-2-hydroxy-1-(phenylmethyl)propyl]-2-methyl-  
, [1S-[1R\*(S\*),2S\*]]-;
- 15 2,6,10,12-tetraazatetradecanamide, 8-hydroxy-  
N,4,13,13-tetramethyl-10-(3-methylbutyl)-5,11-dioxo-7-  
(phenylmethyl)-, [4R-(4R\*,7S\*,8R\*)]]-;
- 20 2,6,10,12-tetraazatetradecanamide, 8-hydroxy-  
N,4,13,13-tetramethyl-10-(3-methylbutyl)-5,11-dioxo-7-  
(4-fluorophenylmethyl)-, [4R-(4R\*,7S\*,8R\*)]]-;
- 25 Butanediamide, N<sup>1</sup>-[2-hydroxy-3-[(phenylmethyl)(1-  
pyrrolidinylcarbonyl) amino]-1-(phenylmethyl)propyl]-2-  
[(2-quinolinylcarbonyl) amino]-, [1S-[1R\*(R\*),2S\*]]-;
- 30 Butanediamide, N<sup>1</sup>-[2-hydroxy-3-[(4-  
fluorophenylmethyl)(1-pyrrolidinylcarbonyl) amino]-1-  
(phenylmethyl)propyl]-2-[(2-quinolinylcarbonyl) amino]-,  
[1S-[1R\*(R\*),2S\*]]-;
- 35 Butanediamide, N<sup>1</sup>-[2-hydroxy-3-[(3-methylbutyl)(4-  
morpholinylcarbonyl) amino]-1-(phenylmethyl)propyl]-2-  
[(2-quin linylcarbonyl) amino]-, [1S-[1R\*(R\*),2S\*]]-;
- Butan diamide, N<sup>1</sup>-[2-hydroxy-3-[(4-  
flu rophenylmethyl)(4-m rph linylcarbonyl) amino]-1-

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(phenylmethyl)propyl]-2-[(2-quinolinylcarbonyl)amin]-,  
[1S-[1R\*(R),2S\*]]-;

Butanediamide, N<sup>1</sup>-[2-hydroxy-3-[(4-  
5 fluorophenylmethyl)(1-piperidinylcarbonyl)amino]-1-  
(phenylmethyl)propyl]-2-[(2-quinolinylcarbonyl)amino]-,  
[1S-[1R\*(R\*),2S\*]]-;

Butanediamide, N<sup>1</sup>-[3-[[[(1,1-  
dimethylethyl)amino]carbonyl](3-methylbutyl)amino]-2-  
10 hydroxy-1-(phenylmethyl)propyl]-2,3,3-trimethyl-, [1S-  
[1R\*(2S\*),2S\*]]-;

Butanediamide, N<sup>1</sup>-[3-[[[(1,1-  
dimethylethyl)amino]carbonyl](3-methylbutyl)amino]-2-  
15 hydroxy-1-(4-fluorophenylmethyl)propyl]-2,3,3-trimethyl-  
, [1S-[1R\*(2S\*),2S\*]]-;

Butanediamide, N<sup>1</sup>-[3-[[[(1,1-  
dimethylethyl)amino]carbonyl](3-methylbutyl)amino]-2-  
20 hydroxy-1-(phenylmethyl)propyl]-2,3-dimethyl-, [1S-  
[1R\*(2S\*,3R\*),2S\*]]-;

Butanediamide, N<sup>1</sup>-[3-[[[(1,1-  
dimethylethyl)amino]carbonyl](3-methylbutyl)amino]-2-  
25 hydroxy-1-(4-fluorophenylmethyl)propyl]-2,3-dimethyl-,  
[1S-[1R\*(2S\*,3R\*),2S\*]]-;

Butanoic acid, 4-[3-[[[(1,1-  
dimethylethyl)amino]carbonyl](3-methylbutyl)amino]-2-  
30 hydroxy-1-(phenylmethyl)propyl]amino-2,2,3-trimethyl-4-  
oxo-, [1S-[1R\*(3S\*),2S\*]]-;

Butanoic acid, 4-[3-[[[(1,1-  
dimethylethyl)amino]carbonyl](3-methylbutyl)amino]-2-  
35 hydroxy-1-(4-fluorophenylmethyl)propyl]amino-2,2,3-  
trimethyl-4-oxo-, [1S-[1R\*(3S\*),2S\*]]-;

Butaneamide,



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2-(acetylamino)-N-[3-[[[(1,1-dimethyl ethyl)amino]carbonyl](3-methylbutyl)amin ]-2-hydroxy-1-(phenylmethyl)propyl]-3,3-dimethyl-, [1S-[1R\*(R\*),2S\*]]-;

5

Butaneamide,

2-(acetylamino)-N-[3-[[[(1,1-dimethylethyl)amino]carbonyl](3-methylbutyl)amino]-2-hydroxy-1-(4-fluorophenylmethyl)propyl]-3,3-dimethyl-,  
10 [1S-[1R\*(R\*),2S\*]]-;

Butaneamide,

2-(acetylamino)-N-[3-[[[(1,1-dimethylethyl)amino]carbonyl](4-fluorophenyl-methyl)amino]-2-hydroxy-1-(phenylmethyl)propyl]-3,3-dimethyl-, [1S-[1R\*(R\*),2S\*]]-;

15

Butaneamide,

2-[(2,2-dimethylaminoacetyl)amino]-N-[3-[[[(1,1-dimethylethyl)amino]carbonyl](3-methylbutyl)amino]-2-hydroxy-1-(phenylmethyl)propyl]-3,3-dimethyl-, [1S-[1R\*(R\*),2S\*]]-.

20

or;

25

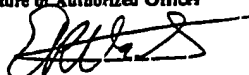
Butanediamide, N<sup>1</sup>-[3-[[[(1,1-dimethylethyl)amino]carbonyl](3-methylbutyl)amino]-2-hydroxy-1-(phenylmethyl)propyl]-3-[(2-quinolinylcarbonyl)amino]-, [1S-[1R\*(R\*),2S\*]]-

30

# INTERNATIONAL SEARCH REPORT

International Application No

PCT/US 91/08613

<b>I. CLASSIFICATION OF SUBJECT MATTER</b> (If several classification symbols apply, indicate all) <sup>6</sup>		
According to International Patent Classification (IPC) or to both National Classification and IPC Int. Cl. 5                      C 07 D 215/48                      C 07 D 295/13                      C 07 C 311/46 C 07 C 311/47                      C 07 C 317/50                      C 07 C 323/60                      C 07 C 275/14, 275/16 275/24, 275/26                      C 07 K 5/02, 5/06                      A 61 K 31/17, 31/33, 37/02		
<b>II. FIELDS SEARCHED</b>		
Minimum Documentation Searched <sup>7</sup>		
Classification System	Classification Symbols	
Int. Cl. 5	C 07 C                      C 07 D                      C 07 K	
Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched <sup>8</sup>		
<b>III. DOCUMENTS CONSIDERED TO BE RELEVANT<sup>9</sup></b>		
Category <sup>10</sup>	Citation of Document, <sup>11</sup> with indication, where appropriate, of the relevant passages <sup>12</sup>	Relevant to Claim No. <sup>13</sup>
X	GB,A,2200115 (SANDOZ) 27 July 1988, see claims (cited in the application) -----	1-67
X	EP,A,0264795 (MERCK) 27 April 1988, see claims (cited in the application) -----	1-67
<div style="display: flex; justify-content: space-between;"> <div style="width: 45%;"> <p><sup>10</sup> Special categories of cited documents:</p> <p>"A" document defining the general state of the art which is not considered to be of particular relevance</p> <p>"E" earlier document but published on or after the international filing date</p> <p>"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)</p> <p>"O" document referring to an oral disclosure, use, exhibition or other means</p> <p>"P" document published prior to the international filing date but later than the priority date claimed</p> </div> <div style="width: 45%;"> <p>"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention</p> <p>"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step</p> <p>"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.</p> <p>"A" document member of the same patent family</p> </div> </div>		
<b>IV. CERTIFICATION</b>		
Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report	
02-03-1992	03.04.92	
International Searching Authority	Signature of Authorized Officer	
EUROPEAN PATENT OFFICE		
Els Vonk		

## FURTHER INFORMATION CONTINUED FROM THE SECOND SHEET

V. ☒ OBSERVATION WHERE CERTAIN CLAIMS WERE FOUND UNSEARCHABLE <sup>1</sup> Partially

This International search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☒ Claim numbers 68-77, 118-122, 165-169 because they relate to subject matter not required to be searched by this Authority, namely:

"Remark: Although claims 68-77, 118-122, 165-169 are directed to a method of treatment of the human/animal body, the search has been carried out and based on the alleged effects of the compounds.

2. ☒ Claim numbers 1-169 Incompletely because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

The use of terms such as heteroaryl and heterocyclyl are in contradiction to the requirements of Art. 6 PCT. The search was performed on the basis of those claims which are clear and concise and of those examples in the description which are complete and correct.

3. ☐ Claim numbers because they are dependent claims and are not drafted in accordance with the second and third sentences of PCT Rule 6.4(a).

VI. ☐ OBSERVATIONS WHERE UNITY OF INVENTION IS LACKING <sup>2</sup>

This International Searching Authority found multiple inventions in this International application as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this International search report covers all searchable claims of the international application
2. ☐ As only some of the required additional search fees were timely paid by the applicant, this International search report covers only those claims of the international application for which fees were paid, specifically claims:
3. ☐ No required additional search fees were timely paid by the applicant. Consequently, this International search report is restricted to the invention first mentioned in the claims; it is covered by claim numbers:
4. ☐ As all searchable claims could be searched without effort justifying an additional fee, the International Searching Authority did not invite payment of any additional fee.

## Remark on Protest

- ☐ The additional search fees were accompanied by applicant's protest.
- ☐ No protest accompanied the payment of additional search fees.

**ANNEX TO THE INTERNATIONAL SEARCH REPORT  
ON INTERNATIONAL PATENT APPLICATION NO.**

US 9108613  
SA 54458

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report. The members are as contained in the European Patent Office EDP file on 17/03/92  
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
GB-A- 2200115	27-07-88	AU-A- 1037588	01-09-88
		BE-A- 1002212	16-10-90
		CH-A- 676988	28-03-91
		DE-A- 3800591	04-08-88
		FR-A- 2609716	22-07-88
		JP-A- 1019053	23-01-89
		LU-A- 87110	23-08-88
		NL-A- 8800100	16-08-88
		SE-A- 8800169	22-07-88
EP-A- 0264795	27-04-88	DE-A- 3635907	28-04-88
		AU-A- 7982387	28-04-88
		JP-A- 63112548	17-05-88
		ZA-A- 8707950	26-04-88